MINING METHODS AND COSTS AT CRYSTAL-VICTORY AND MINERVA NO. 1 FLUORSPAR MINES OF MINERVA OIL CO., HARDIN COUNTY, ILL.

By Gill Montgomery, J. J. Daly, and Frank J. Myslinski

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MINING METHODS AND COSTS AT CRYSTAL-VICTORY AND MINERVA NO. 1 FLUORSPAR MINES, MINERVA OIL CO., HARDIN COUNTY, ILL.[1]

by

Gill Montgomery,[2] J. J. Daly,[3] and Frank J. Myslinski[4]

SUMMARY

This report covers operations at the Crystal-Victory and Minerva No. 1 mines in Hardin County, Ill., which are operated by the Minerva Oil Co., Fluorspar Division, with offices in Eldorado. It describes the exploration, development, and mining practices, giving costs of each. Transportation, equipment, power, labor, and other influencing factors also are discussed.

The mining methods employed are those most applicable to the flat-bedded replacement deposits common to the Cave-in-Rock section of the Southern Illinois fluorspar district. The fluorspar beds occur from surface exposures to 1,000 feet deep.

In this district churn drilling is the method practiced for exploring flat-bedded deposits from the surface. Aerial photography and geochemical methods for indicating mineralization have been helpful in planning a drilling program. A program usually includes enough drilling to obtain only sufficient data on the value of the ore body and its structure to justify initial development and purchase of the mineral rights under option.

Early development at the Minerva No. 1 and Crystal-Victory mines comprised access by vertical shaft with subsequent development of the ore body by narrow haulage drifts. These drifts were enlarged and the pillars trimmed to provide working clearances for diesel trucks and mechanized loading equipment. At the Crystal-Victory mine adits for truck haulage were driven into the hillside to supplement, if not eliminate, the small capacity and costly vertical shaft and hoisting facilities.

Breast stoping (locally called room and pillar) is the method used to extract the ore. Roof bolts are used to supplement pillars in areas of weak roof structure.

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Percussion-type drills mounted on airlegs or jumbos are used for blasthole drilling.

Ore is mechanically loaded into diesel trucks for transport from the production face to the primary crusher.

The operation of diesel-powered equipment is made possible by the equitable use of hoisting shafts, auxiliary shafts, drill holes, adits and mechanical blowers and exhausters to provide adequate circulation of fresh air throughout the workings.

Any new equipment or practice is thoroughly tested and studied before being accepted by the management.

INTRODUCTION

The purpose of this report is to disseminate useful information on methods and procedures employed in mining relatively flat-lying fluorspar deposits of fairly uniform thickness. In the Cave-in-Rock fluorspar district, where such deposits occur, the Minerva Oil Co., Fluorspar Division, presently owns and operates two mining properties--the Minerva No. 1 and Crystal-Victory mines--and leases three other properties--the Austin-Benzon, the Austin-Cleveland, and the Austin-Defender.

Numerous improvements in operating practices and equipment used in drilling, blasting, loading, and underground transportation have been made since the last Bureau of Mines publication[5] on mining methods in this district. Rising labor and supply costs, mining low-grade ore, and increased sales competition required revolutionary development of special equipment and the introduction of new ideas. Adoption of these innovations, which proved to be practical after thorough testing, resulted in reduced operating costs through greater productivity per man-hour.

Minerva No. 1 mine ore is beneficiated at the Minerva No. 1 mill. Three concentrates are produced: Ceramic-grade fluorspar, acid-grade fluorspar, and zinc sulfide. The ceramic grade is further subdivided into three grades of purity: No. 1 ceramic (95-96 percent CaF_2), special ceramic (92.5-94 percent CaF_2), and No. 2 ceramic (85-90 percent CaF_2). Acid-grade fluorspar must be 97 percent CaF_2 or better, with silica less than 1.10 percent. Two general grades (60 and 70 percent effective) of metallurgical gravel fluorspar are usually produced. The effective content is defined as the fluorspar analysis, minus 2.5 percent of fluorspar for each 1 percent of SiO_2 contained.

The Crystal-Victory mine ore is treated at the adjacent Crystal mill, also operated by the Fluorspar Division of Minerva Oil. Heavy-media and flotation processes are used. Four concentrates are produced: Metallurgical gravel fluorspar, acid-grade fluorspar, zinc, and lead sulfide. The

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[5] Needham, A. B., Methods and Costs of Mining Fluorspar From a Flat-Bedded Deposit at Cave-in-Rock, Illinois: Bureau of Mines Inf. Circ. 7514, 1949, 10 pp.

Crystal-Victory mill is completely flexible and can take not only Crystal-Victory ore but has facilities to handle ore from outlying company mines and from independent mine operators. The company purchases small quantities of custom ores, usually for blending purposes, from the independent operators.

ACKNOWLEDGMENTS

Appreciation is expressed to O. E. Anderson, plant manager at Minerva No. 1 mine; I. V. Robertson, plant manager of Crystal-Victory properties; and Don Saxby, chief geologist, Gordon McDowell, safety director, Raynard Dutton, D. B. Holbrook, Floyd Callahan, Gatha Stacy, and the production men for their assistance in obtaining data for this report.

LOCATION AND PHYSICAL FEATURES

The Minerva No. 1 mine is in sec. 24, T. 11 S., R. 9 E, and sec. 19, T. 11 S., R. 10 E, Hardin County, Ill. From the town of Cave-in-Rock on the Ohio River, this mine can be reached by traveling 5-1/2 miles due north on Illinois Highway No. 1 and a secondary road. (See fig. 1.)

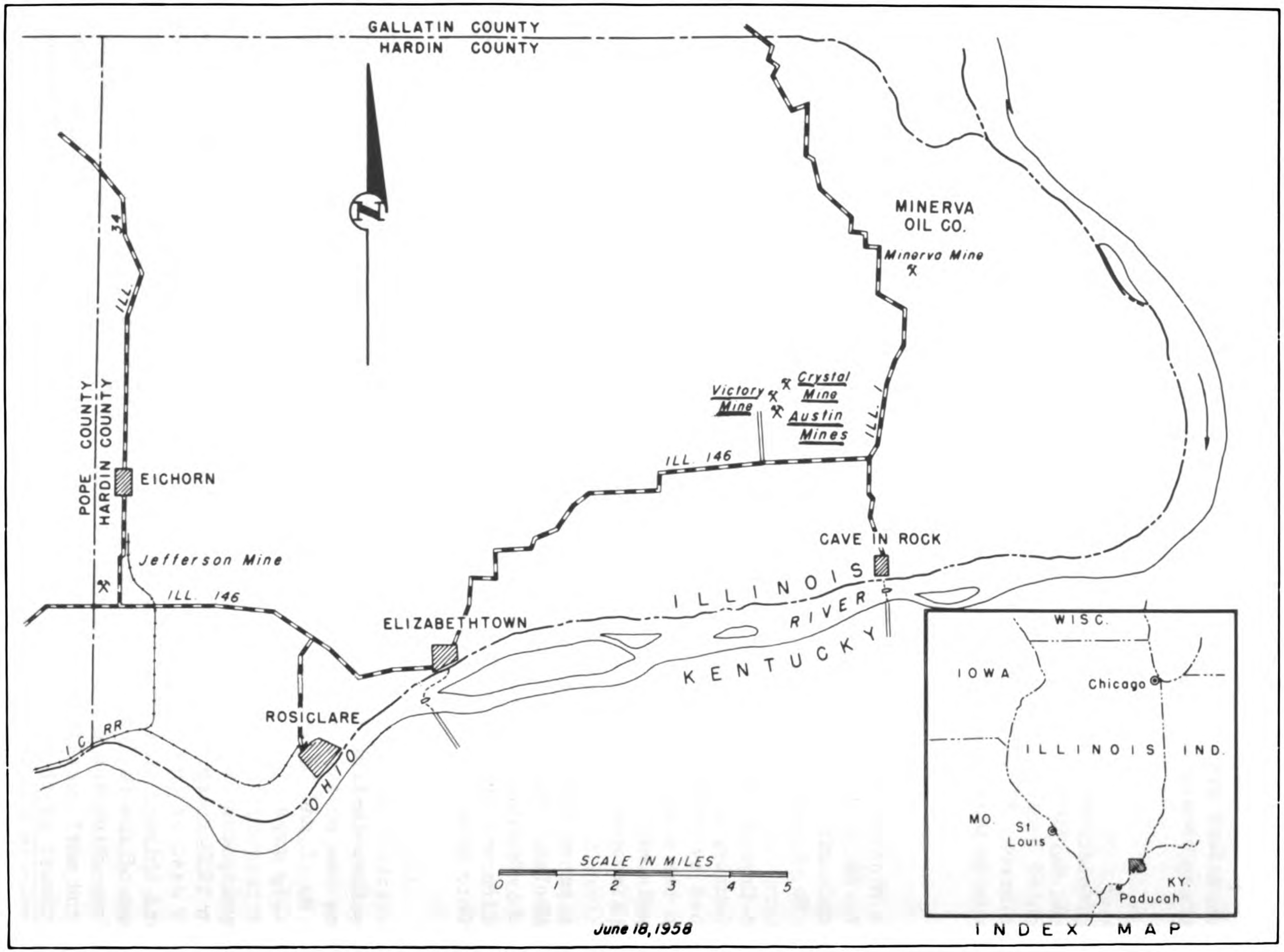
The Crystal-Victory mine is in sec. 34 and 35, T. 11 S., R. 9 E, in Hardin County, Ill. From the intersection of highways 146 and 1, the mine can be reached by traveling 1.7 miles west on Highway 146 to a company road that leads to the mine. This road is surfaced with crushed stone obtained from the heavy media mill tailings, which consist principally of 3/4- by 1-1/2-inch crushed limestone rock. (See fig. 1.)

The mines are in an area characterized by gently rolling hills and numerous sinkholes. Sinkholes indicate the existence of a strong underground drainage. Good all-weather roads connect the mines to rail shipping points at Junction and Rosiclare, Ill., and to company-owned barge-loading facilities on the Ohio River at Cave-in-Rock.

HISTORY AND PRODUCTION

The Cave-in-Rock fluorspar area was well known by 1903 but did not reach prominence as an important fluorspar-producing area until 1918. The Minerva Oil Co. No. 1 and Crystal-Victory mines are currently important producers within this area.

Development of the Victory mining area was begun by sinking the Carlos shaft in 1927 to check the continuity of a productive ore zone on an adjacent property east of the Carlos shaft. From this opening the first ton of ore was mined and hoisted in 1928. In 1929 diamond drilling detected another ore body southwest of the Carlos shaft, and the management decided to sink the Addison shaft from which the deposit was developed in 1930. Further exploration by drifts and surface diamond drilling extended the limits of the ore zone west and northwest of the Carlos shaft. In addition, the Federal Bureau of Mines



June 18, 1958

FIGURE 1. Location Map, Minerva Oil Co. Mines in Cave-In-Rock Fluorspar Area, Hardin County, Ill.

Original from THE OHIO STATE UNIVERSITY

conducted an underground core-drilling program at the Victory Fluorspar mine from October 1943 to March 1944.[6]

Initial development of the Crystal property consisted of an adit driven into a hillside in 1929. This adit disclosed one of the principal ore bodies on the property and led to extensive development of other ore bodies. A total of 10 shafts were sunk on the property by 1952, when the property of the Crystal Fluorspar Co. was purchased by the Minerva Oil Co., Fluorspar Division. The Crystal property was operated by the Minerva Oil Co. as a separate mining operation from 1952 to 1955, when operations of the Crystal and Victory properties were combined into the present operating unit.

The Victory mine was purchased by the Minerva Oil Co. in 1955. At the same time they also leased the adjacent Austin-Defender mine to obtain access to the Victory mine through an adit and haulage drifts entering near the old Carlos-shaft area. The Austin-Defender and the two other mines leased by the company (the Austin-Benzon and Austin-Cleveland) are part of the same ore body group as the Victory mine and the oldest workings in the Cave-in-Rock area exploited by adits from surface outcrops. The company has mined the Austin-Defender and the Austin-Benzon, which are subject to further prospecting below the floor of the mining level. The Austin-Cleveland is being prospected now.

The discovery hole on the westerly of the two Minerva main ore bodies was completed in December 1940, and by July 1942 enough reserves were blocked by churn and diamond drilling to begin development of the ore body through the present hoisting shaft. The shaft is on the Roxie Ledbetter farm, which is also the present site of the Minerva No. 1 flotation mill. The shaft was bottomed at 644 feet in September 1943. The rock formation at the collar is Tar Springs sandstone, and the shaft sump is in the top of the Rosiclare sandstone. Mine production at the Minerva No. 1 mine from 1945 to 1957 amounted to 889,078 short tons of crude ore hoisted. The Victory mine output from 1928 to 1957 was approximately 415,000 short tons of crude ore. From 1952 to 1957, inclusive, 291,901 short tons of crude ore had been mined from the Crystal mine.

The following table showing production of crude ore and shipments of finished fluorspar from the Illinois Fluorspar District was compiled from data in the Federal Bureau of Mines.

TABLE 1. - Recorded mine production and shipments, in short tons

Year	Crude ore produced	Finished fluorspar shipped
1948...	415,472	172,561
1949...	301,412	120,881
1950...	364,587	154,623
1951...	528,863	204,328
1952...	494,565	188,293
1953...	467,132	163,303
1954......	259,284	107,830
1955......	465,208	166,337
1956......	587,225	178,254
1957......	533,684	169,939
1948-57...	4,417,432	1,626,349

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[6] Bishop, O. M., and Swanson A. S., Core Drilling at the Victory Fluorspar Mine, Hardin County, Illinois: Bureau of Mines Rept. of Investigations 4324, 1948, 8 pp.

GENERAL GEOLOGY AND DESCRIPTION OF DEPOSITS

The Cave-in-Rock fluorspar mining area lies in the eastern part of Hardin County north of the town of Cave-in-Rock. This area includes part or all of secs. 23 to 27 and 33 to 36, T. 11 S., R. 9 E.; secs. 28 to 33, T. 11 S., R. 10 E; secs. 1 to 5, T. 12 S., R. 9 E; and secs. 3 to 10, T. 12 S., R. 10 E.

The surface rock exposures in the area are of the Chester and Iowa serie of the Mississippian system, which consists of alternate limestone, sandstone, and shale beds. (See fig. 2.) The regional dip of these sediments is 2.75° to 3.50° northeast.

The major structural feature of the area is the Peters Creek fault zone, which forms the western boundary of the area. This major fault zone trends N. 50° E. The mineralization of the area is associated with minor faults lying southeast of and parallel to the Peters Creek fault zone. These faults trend N. 45° E. to N. 60° E. Also associated with the mineralization are several fracture systems trending N. 30° W. and N. 85° W.

Deposits were formed when limestones of the Chester and Iowa series were replaced selectively by hydrothermal solutions rising along these minor fault and fractures, which lose their displacement at progressively shallower depths. The favored replacement zones consist of the upper Renault, the Levias, the upper Fredonia, and, just below, the Sub-Rosiclare formation of the Fredonia beds. (See fig. 3.) Regional thrust forces from a southeasterl direction have compressed the formations and at times inhibited free movement of rising solutions, particularly through softer shale formations. In localized areas flat voids developed at the interfaces of competent and incompeten rock beds into which mineralizing solutions penetrated and replaced adjacent limestone layers, resulting in the "coon tail" appearance of much of the ore, typical of the Crystal-Victory mine.

The mineral deposits of the area contain fluorspar, sphalerite and galena, with greenockite, gallium, and germanium sulfide as important components of the sphalerite. Associate minerals include calcite, quartz, barite, witherite, strontianite, chalcopyrite, pyrite, marcasite, smithsonite, cerussite, and malachite.

The ore produced at Minerva No. 1 occurs in the upper Renault limestone and is a fluorspar-sphalerite mixture, the sphalerite contains important cadmium, germanium, and gallium values. The productive horizons at the Crystal-Victory mine range from the upper Renault to the Sub-Rosiclare. Thes ores consist largely of sulfide-free fluorspar in the upper Renault, Levias, and top of the upper Fredonia beds. In some areas the upper Fredonia contain considerable sphalerite and lead with the fluorspar. The sulfide ores occur from the base of the Rosiclare to the top of the Sub-Rosiclare, but the deepe levels are generally richer in lead and zinc values.

Ore bodies in the district range up to 3 miles in length and from 10 to more than 300 feet in width; the ore is 3 to approximately 20 feet high with

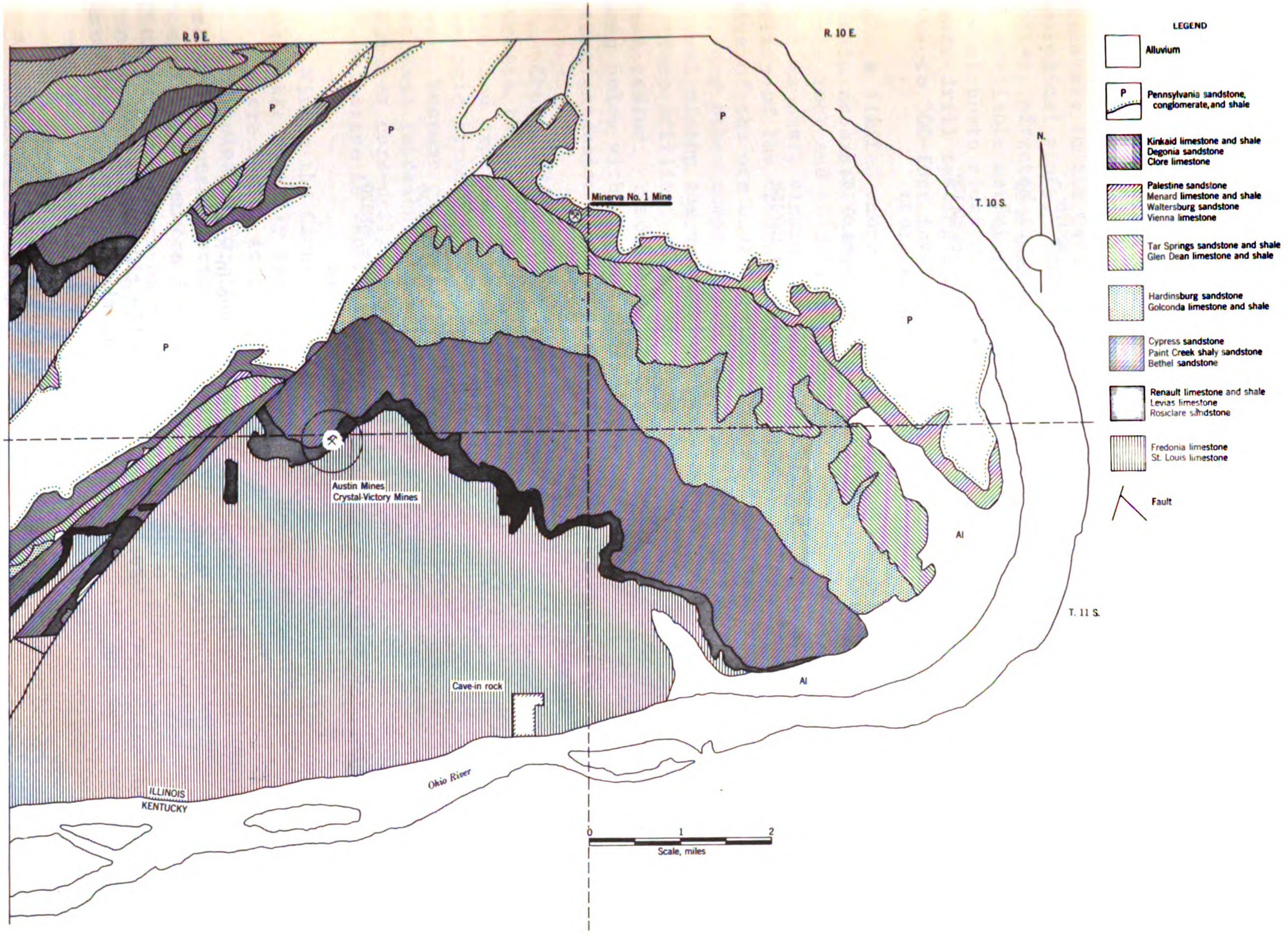

FIGURE 2. - Geologic Plan Map Showing Major Trends.

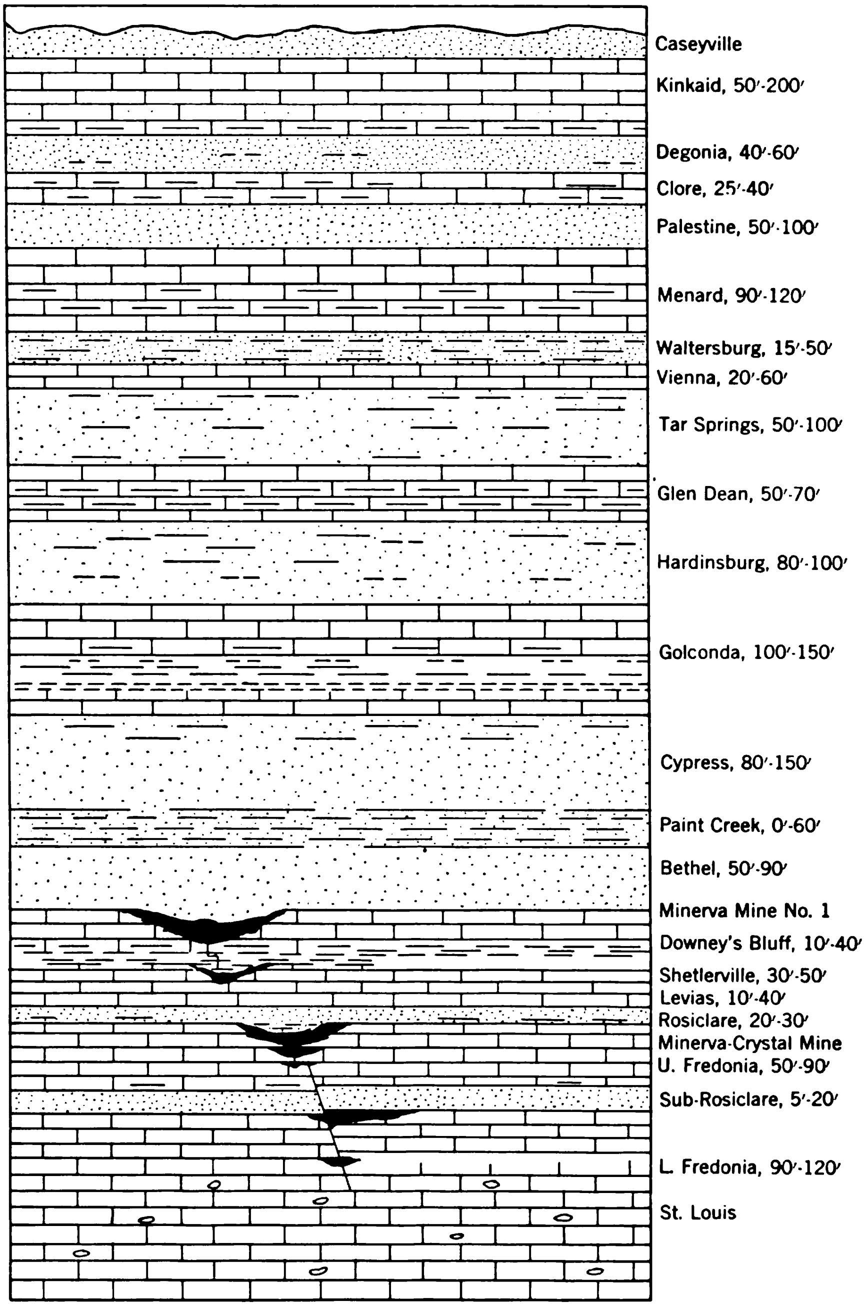

FIGURE 3. - Stratigraphic Section, Typical of Cave-In-Rock Fluorspar Area.

an average of about 9-1/2 feet. Ore bodies are normally thickest along the controlling fracture zone and gradually get thinner at the margins, against the roof.

METHODS OF PROSPECTING AND EXPLORATION

Much of the Cave-in-Rock area has been prospected at shallow depths, as evidenced by the number of small pits and shafts found scattered throughout the area. This method of prospecting continues to be favored by local residents, but lack of available outcrops and signs of mineralization make it necessary for the mining companies to select favorable areas by studying airphotos, followed by surface examinations and mapping for guidance in locating drill holes to obtain subsurface geological information. Typical of the practice was the discovery of the Minerva No. 1 mine, and the several ore bodies forming the nearby ore reserve of the company. It was the first known major discovery in the Cave-in-Rock fluorspar area that can be credited to photogeological study. Fracture zones, which control the position of the ore bodies, affected the drainage pattern at the surface and could be detected on available aerial photos made by the Agricultural Adjustment Administration. The airphoto clues were checked by an extensive ground study, followed by churn-drill testing of the verified trends, cross sectioning these trends at 200- to 500-foot intervals.

A limited amount of drilling from drill sites on the surface is done to obtain accurate information on the structure of detected ore and surrounding waste rock and to delineate enough ore to justify initial development costs, such as shaft sinking or tunneling from adjacent working areas. It is not the policy of the company to keep drilling surface holes until the tenor and tonnage of the ore have been outlined as accurately as possible. The Minerva Oil Co. and other companies in the area have found a greater tonnage of ore by normal mining and underground exploration practices than could be found by surface drilling. This has been particularly true where total widths have not been tested. The bulk of the exploratory work is done underground by drilling long holes with diamond core drills or short holes with percussion drills using extension steel and by headings developed in normal mining.

Churn drills are preferred instead of diamond drills to probe for ore beneath the surface. Generally, thick layers of blocky sandstone overlie the ore, and experience has proved that churn drilling is more adaptable to the geologic structural conditions in this area than diamond drilling. Furthermore, because of the larger diameter hole, samples taken from the churn-drill cuttings represent the material being penetrated better than the smaller diameter core-drill samples. Also, the churn drill holes are large enough to be effective in ventilating stopes during mining operations.

Within the Cave-in-Rock fluorspar area, the Minerva Oil Co. surface drill holes are normally spotted on 200- to 500-foot centers along the general trend of the ore bodies in the drilling area. When mineralization is encountered, a line of holes on 25- to 50-foot centers is drilled normal or diagonal to the trend of mineralization to obtain a cross section of the mineralized area. The distance between lines of holes also is reduced when ore has been detected. The spacing depends on many factors, of which the following are the most important: (1) Cost of drilling holes to considerable depths to penetrate a favorable horizon, (2) uniformity and continuity of ore bodies, (3) limitations of drilling locations by surface topography. Generally, the deposits in the Cave-in-Rock fluorspar area occurring at the greatest depths show the greatest uniformity and continuity; the shallow deposits are usually less uniform and continuous. From the viewpoint of drilling costs, this condition is fortunate, because the shallow deposits require much closer spacing of holes than do those occurring at greater depths.

The company has developed underlying and parallel ore bodies along the main trends by horizontal, angled, and vertical diamond drilling from stoped-out areas in the mine. The holes are drilled to distances ranging from 40 to 600 feet. Air-operated core-drilling machines are used for this purpose, and all holes are drilled AX size. In addition, airleg percussion drills with extension steel are used to drill exploratory holes from 20 to 40 feet in length. They are frequently used to check offsets behind waste rock, parallel runs and veins, and mineralization possibilities above mine roof and below stope floors.

Contract Drilling

The company prefers using contract drillers because of their high degree of efficiency and experience in this particular field. With limited drilling programs, the management doubts whether they are justified in employing a full-time drilling crew and equipment that requires costly tools and replacement parts to conduct an efficient drilling program.

Churn drill holes, bottoming at 6-1/2-inch diameters, are drilled by a contractor at a flat rate of $2.75 per foot plus $0.25 per foot for casing when required. There is no charge by the contractor for placing casing through soil cover. Reclaimed 8-inch-inside-diameter oil-well pipe is used for casing churn-drill holes to bedrock, and, when necessary, to the bottom of the hole. The company supplies the pipe. It is obtained in 20-foot lengths and comes with a sleeve-type coupling. A churn-drilling crew will usually net 30 feet of hole per shift under normal operating conditions. The churn-drill bits are sharpened and tempered at the drill site.

Diamond drilling from the surface is contracted currently at a base rate of $2.65 per foot of AX hole, using a coring bit that produces a 1-1/8-inch-diameter core. Additional charges for moving, reaming, casing, bit and rod loss, and cementing when needed will increase this charge to an average of $3.05 per foot.

All underground diamond drilling with a core bit is done by a local contractor. The drilling contractor drills an AX-size hole from which a 1-1/8-inch-diameter core is obtained at a contract rate of $2.40 a foot. In addition, the Minerva Oil Co. will pay the drilling contractor for the drillers o a straight hourly basis, for all time in excess of 4 hours for setting up the drill. Compressed air and water is supplied by the company; if diamond drillers are required to set up supply lines, the hourly wage of the drillers for this work is recompensed by the Minerva Oil Co.

Sampling

Surface churn drill holes are sampled at 5-foot intervals when going through barren rock and at 2-1/2-foot intervals when going through a mineralized formation. Samples taken at these intervals accurately represent individual beds of ore ranging in thickness from a few inches to 5 feet. Changes in the sampling interval are made by the driller if he recognizes an increase in the penetration rate of the bit when it reaches the ore horizon. Another aid to the driller is to pan a sample of the cuttings bailed out of the hole for signs of ore.

The holes are cleaned at the sampling intervals by means of a bailer. It consists of a cylindrical pipe with a trapdoor arrangement at the base, allowing the sludge to enter on the downstroke and closing when the bailer is pulled out of the hole. A suitable container, usually a tub, is used to hold the cuttings recovered by the bailer. Approximately 1-pound samples of the churn-drill cuttings are taken from each run, placed in mounds, and tagged in a sequence to correspond with the footage drilled in each run. The cuttings remaining in the container are discarded.

The samples of cuttings are observed by the geologist and logged. Samples showing mineralization are bagged in sacks and sent to the company laboratory at the Minerva No. 1 mine property for chemical analysis. Core obtained from surface and underground diamond drilling is logged by the geologist, then entire sections of the core showing mineralization are sent to the laboratory for chemical analysis. The remainder of the core is discarded. When using extension steel with percussion drills for prospecting, the driller obtains a representative sample at 5-foot intervals by recovering drill cuttings from each hole as it is drilled. These cuttings are collected in cloth bags and examined under low power magnification by the geologist for evidences of ore. The working faces are not sampled, but an experienced geologist can recognize ore of minable grade by visual inspection.

The geological department is constantly alert for "sweetening" of the samples taken from churn-drill holes. Enrichment of the cuttings is commonly caused by cave-ins or by jarring the upper portion of the bit, hitting the walls of the hole and causing material to ravel into the hole. This added material distorts the value of the cuttings. Since the formations are definitely recognizable, the geologist is usually able to determine by observation when a percentage of the cuttings fails to correspond to the formation penetrated by the drill at the sampling interval.

All surface and underground exploration and prospecting holes are surveyed and then spotted on maps by the engineering department. A code system for indicating ore values, subore values, traces and blank holes is used on these maps to permit visual indications of ore trends.

Estimation of Tonnages and Values

Completed surface drill holes are plotted in plan and section to delineate the area and thickness of ore zones, commonly called ore blocks, for the purpose of calculating ore reserves of undeveloped mineralized areas.

On the basis of data obtained from surface diamond core and churn drilling, a geologist determines the limits in area to which an ore block may pply. The tenor of the ore and the distance between holes, as well as personal experience of the geologist in the district, are criteria in determining the area to be included in the ore block. Once the outline of the ore block is determined, the surface area is found by actual scale measurements, the vertical extent by averaging the ore thickness indicated by drilling, and the grade by weighted averages of assay results. A tonnage factor of 12 cubic feet per ton of ore is used to calculate the tonnage in the blocks. Tonnage and grade are then adjusted to the dilution factor, which is a function of the minimum height that will accommodate the proposed mine loading and haulage equipment.

DEVELOPMENT

Before the Minerva Oil Co. purchased the Crystal-Victory properties, the ore bodies were exploited through shallow shafts that bottomed in the ore. This was done intentionally to keep development costs at a minimum. After the shaft was completed, virtually all other development work was limited to driving an occasional crosscut through barren zones to connect ore bodies within mineralized areas. Wherever possible, haulage drifts were kept within the ore body.

After the Minerva Oil Co. purchased the Crystal-Victory property, the problem of entry was considered before the management decided that truck haulage would be more economical.

Although several shafts were available for hoisting ore, careful planning showed that an adit driven from the surface to the mined-out Defender workings and continued into the Victory area would result in substantial savings in transportation costs. This adit was driven 10 feet high and 12 feet wide, but frequently the unstable nature of the roof caused an overbreak from the planned height. In the Defender mine the desired clearance was obtained by trimming pillars and the back where necessary. The adit was then continued into the Victory mining area. For safety and efficiency in operation, the unstable roof encountered along the haulageway was held stationary by roof bolts, and the floor ballasted with crushed-rock tailings obtained from the heavy-media plant. The crushed rock roadbed increased efficiency in hauling by cutting down truck travel time, reducing truck maintenance and wear costs, and providing proper drainage. Truck haulage adits and underground roadways have been increased in number and length to reach all existing workings.

Through a study of drill-hole data obtained from the exploration program of the Minerva No. 1 mine property, a shaft site was centrally located between the east and west ore bodies.

> Before sinking the shaft in 1942, it was necessary to grout several pervious strata of sedimentary rocks overlying the ore level. This was done by means of a Bucyrus-Armstrong cable tool drill and a Dowell standard oil-field cementing truck capable of pumping grout at pressures up to 3,000 pounds. Bed rock was encountered by the drill at 15 feet, and 7-inch casing was then cemented in place at 20 feet. The hole was deepened until waterbearing formations were penetrated; then the surface casing was equipped with a Bradenhead, which admitted a 2-inch tube through

which cement could be delivered to the bottom of the hole; a side valve permitted circulation in the hole. A slurry of neat cement was pumped into the hole and the grout was allowed to set under 30 pounds of pressure for 8 hours. Usually, at least three stages of grouting at increasing pressures, even up to 1,500 pounds, were made. Assuming uniform porosity and permeability based upon percentage of voids observed in cuttings from the formations, grout penetrated a radius of 25 feet around the drill hole. In addition to the three water sands near surface, it was necessary to grout those topped at 270, 420, and 530 feet, making six elevations grouted. Only one open fracture in limestone was encountered at 70 feet, necessitating the use of "Gel-Flake" (shredded cellophane) in the cement to gorge the crevice for high-pressure grouting.

The shaft (total depth of 645 feet including a 10 foot-sump) is 5 by 15 feet in cross section and includes two hoisting compartments and a compartment for water columns, ventilation pipe, and manway. No timber was used below the collar, but all shale formations were concreted immediately after being excavated. The concreted sections totaled 197 feet of the total shaft depth.

The next step in the initial development was driving 8 by 8 foot drifts, untimbered, except for intervals of bad ground, under and between the two parallel ore bodies. The ore bodies have a general dip to 3-1/2° to the northeast; therefore, about 500 feet from the shaft the north haulage drift was actually being driven into the west ore body. The haulage level cut the east ore body at a distance of 1,500 feet.

The final stage in developing the ore bodies was the driving of 6 by 6 foot raises on approximately 100 to 150 foot centers from the haulage level into the ore bodies. Nearest the shaft, the ore bodies are about 57 feet above the level, but to the northeast the ore bodies and the haulage level eventually meet. These raises were fitted with chutes through which ore was loaded into side dump cars for haulage to the shaft.7/

A circular shaft, 5-1/2 feet in diameter, was sunk in 1950 in the southwest portion of the east ore body for ventilation and service accommodations; also to provide an aircourse for the efficient removal of air contaminated by the operation of newly acquired diesel loading and hauling equipment. The work for this shaft comprised enlarging a 14-inch churn drill hole to a depth of 555 feet. Shale zones encountered at various depths in the shaft were concreted. Two sets of collapsible steel forms were used for this purpose.

The transition from rail-type haulage to large diesel haulage equipment also brought about a subsequent change in the size of development openings. When driving a haulage drift through barren rock at either mine, the drift size is kept to a minimum of 10 by 12 feet in cross section; however, there is a difference in the drift drilling pattern at each mine. At mine No. 1 a full V-cut is used to make the initial break in the face, but at the

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7/ Work cited in footnote 5, p. 2.

Crystal-Victory mine a 5-hole burn cut is used. A detailed description of the procedure is given under stoping methods, since the practices and equipment used are generally comparable. At each of the mines a two-man crew (a driller and helper), is used to drill and blast a round in one 8-hour shift. On the following shift the blasted rock is picked up by a portable slushing-ramp unit, which scrapes the waste into a truck. At the Minerva mine No. 1 the waste is hauled to a mined-out section of the mine and dumped into an abandoned stope. At the Crystal-Victory mine the waste is either disposed of underground or hauled to the surface by truck for subsequent disposal.

At the Crystal-Victory mine a series of untimbered 5- by 5-foot raises, on approximately 100-foot centers, was driven from a mined-out area on the main mining and haulage level to intersect an ore block known as the Levias L to provide draw points and access to the ore.

The raise round consisted of 21 to 24 holes, drilled to a depth of 6 feet. The average round included a five-hole burn cut, but, when possible, a 6-1/2 inch surface churn drill hole was substituted. This happened when it was convenient to follow the course of a hole that had penetrated the ore zone, main mining, and the haulage level at the proposed starting point of the raise. Substitution usually reduced the normal number of holes and, subsequently, the amount of dynamite required to blast a round efficiently. The large-diameter hole also provided fresh air for the crew when drilling the raise and, in addition, obtained a greater footage advance per round.

An Ingersoll-Rand IR-48 stoper using 1-inch hexagonal drill steel with a throw-away bit was used to drill the raise rounds. The staging from which the driller operated consisted of a wood platform made from 2- by 8-inch lumber sawed to 52-inch-length boards. This platform is supported by four steel pins placed in holes drilled by a jackhammer. The holes were drilled in sets of two on opposite walls of the raise. Additional holes were drilled between staging sets in which pins were placed for access in and out of the raise. The depth of round determined the staging interval.

From the staging platform the miner started his operation by first drilling the cut holes, which bottomed a few inches ahead of the others. Special attention was given to the alinement and direction of these holes, because this operation determined the condition of the walls, staging timber, and pins after a blast. The cut was placed in the center of the round and directed to rifle or hit the bottom of the raise or raise wall free of pins. Subsequent holes were distributed to place an even burden on all holes. The outside holes were drilled as nearly parallel as possible to the direction of advance.

The staging was dismantled before blasting, and the boards hung on pins in the raise by steel hanging straps. The straps were formed into loops and nailed to the boards.

The average raise round used 75 pounds of 1-1/4- by 8-inch Trojan 40C powder, primed with a safety fuse and blasting cap, and ignited with a 12-inch hot-wire-fuse lighter. This type of round broke 95 percent of the depth drilled with satisfactory fragmentation.

The drilling crew consisted of a driller and helper who regularly drilled, loaded, and shot one round per shift. The driller accomplished the task of drilling, loading, and shooting while the helper handled supplies, changed the bits, primed the powder, and generally looked after the needs of the driller. The round was fired by the driller at the end of the shift. During the following shift the broken rock was cleaned up by a slusher loader unit and was loaded into diesel trucks for haulage to the surface mine dump or dumped into an abandoned stope.

MINING METHODS

Early Mining Practices

The Crystal-Victory ore bodies were originally mined from shafts that bottomed in ore. From the shaft drifts were turned off in all directions to the limits of the ore body; however, enough pillars were left in place to protect the shaft and other mine openings. Timber was often used to replace pillars that contained high-grade ore.

Jackhammers were the first machines used by the early miners to drill all production and development faces. Later, column-mounted drills were used, and more recently, jumbo and airleg-mounted drills. The early miners used hand shovels to load blasted ore or waste, and later, mechanical track-mounted overhead loaders and stationary slusher hoists. The hoists were also used to pull loaded cars up steep inclines. Loaded cars were usually hand trammed or powered to the ore-gathering station. All mechanical loading and transportation equipment required rail facilities.

There has been a definite transition in the use of drilling bits. The first one used was a steel cross bit, made integral with the rod; next, a detachable (threaded) steel cross bit was used; and now the socket-type, single-use crossbit, the multiple-use, socket-type carbide-insert crossbit, or the carbide-insert chisel bit, made integral with the rod, is used.

Present mining practices

The Minerva No. 1 mine and the Crystal-Victory mines are well defined as lens-shaped, flat-lying bedded deposits. In the open stope, breast stoping with the random-pillar method of mining was adopted at these mines because of this favorable condition. At the Minerva Oil Co. mines, modern mining methods and equipment were used to lower the cost of drilling, blasting, scraping, loading, and transporting the broken rock. This equipment and these practices increased the total tons produced per man shift, but at the same time they involved increased dilution, because of the size of the openings required, and decreased selective mining of the ore.

The current method of mining has been a normal transition from early mining practices. However, as operations in the Cave-in-Rock area parallel those in the Tri-State (Missouri, Kansas, Oklahoma) mining district, the Minerva Oil Co. has applied or adopted to a large extent the equipment used in that district.

Currently the accepted practice is to mine the full width of the ore along its strike, which eliminates the rehanging of air, power, ventilatio and waterlines, and concentrates mining operations to a limited area. Thi practice permits maximum utilization of mechanical equipment.

The stope faces are advanced by driving drifts irregularly across the full width of the ore body. They are driven at intervals in variable cross sections determined by the height of the ore, by the span that the back wil stand unsupported, and by the strength of the supporting pillars. When the drifts are advanced two to four rounds, the faces are enlarged by slabbing t walls to connect to adjoining drifts.

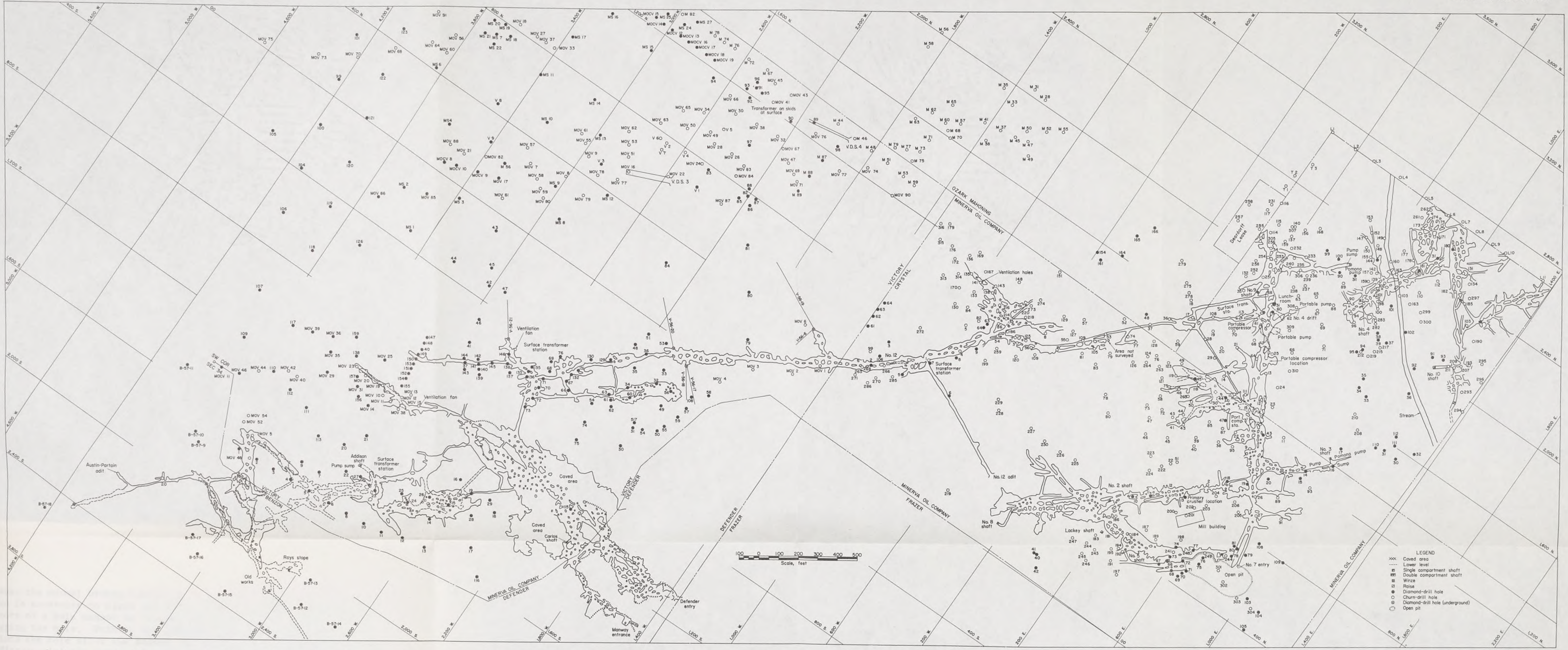
Pillars are left at random intervals when drifts are interconnected in t normal process of mining and represent approximately 25 percent of the total area mined. Generally, pillar spacing varies from 25- to 60-foot centers, a range in thickness from 10 to 40 feet. (See figs. 4 and 5.)

Final pillar extraction is begun when the minable limits of an ore body have been reached. Extraction begins at the outer limits of the ore and retreats toward the main shaft or haulageway. Alternate pillars are mined, and the others trimmed to a point where roof conditions do not permit safe entry into the area. No pillar retreating was done at the Minerva No. 1 as it will be some years before the limits of the ore body along the strike of the fracture system will be reached. However, there has been some pillar removal in the Victory mine in stopes where there were indications that unstable roof co ditions were developing, which would endanger future robbing operations.

Drilling and Blasting

The cross section of a drift round varies with the type of machine used. At the Crystal-Victory and No. 1 mines a blast round drilled with a jumbo averages 12 by 20 feet at the face; when drilled with an airleg drill, it is 10 by 20 feet at the face. The company prefers not to mount airlegs on platforms that will reach heights above 10 feet, since available jumbo equipment is well suited to drilling at such heights. The number of blastholes drilled in a round varies from 28 to 36, which includes either a four- or six-hole V-cut when using drills mounted on jumbos or a 5-hole burn cut when an airleg drill is used. The V-cut is preferred by the miners at the Minerva No. 1 mine, where all drilling is done with jumbo drills.

The cut is placed in a position on the face to give the miner the best results possible. As the ground contains vugs or natural openings within the ore horizon, the miner at times takes advantage of this condition by using the vug or opening as the release hole. However, in most instances, the miner will search for solid ground that will enable him to drill good clean holes for the cut. The collar spacing of holes is left to the judgment of the individual miner but generally ranges from 2-1/2 to 3 feet. When slabbing to turn pillars, a swing round is used to break into adjoining drifts and to trim pillars to their desired shape.



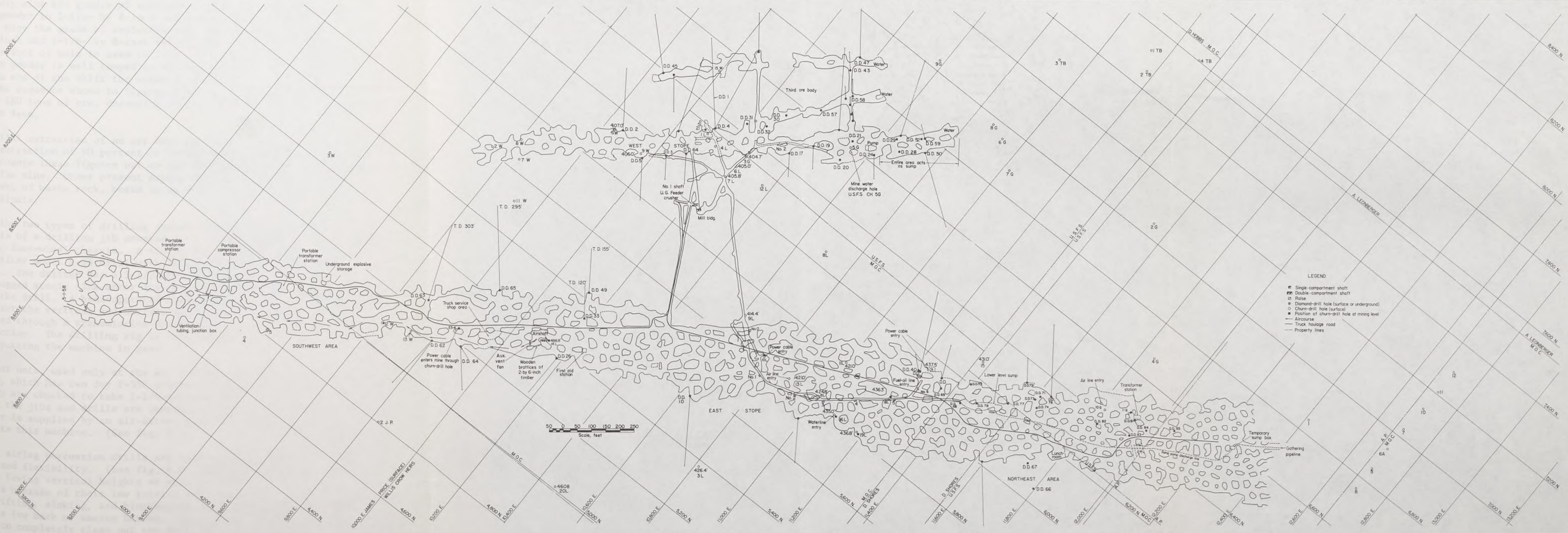


FIGURE 4. (Top) - Plan Map of Crystal-Victory and Adjoining Mine Workings.

FIGURE 5. (Bottom) - Plan Map of Minerva No. 1 Mine Workings.

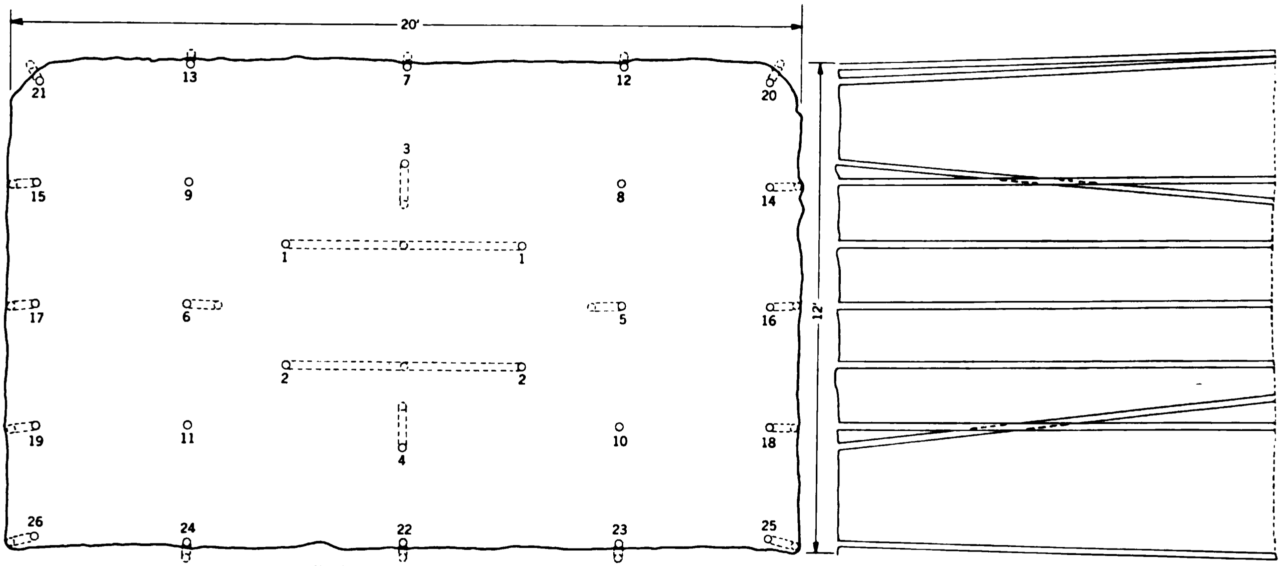
Because the normal broken condition of the ore horizon contains many vugs a blow gun is necessary to clean all holes after drilling. Frequently 10 percent or more of a hole cannot be loaded with explosives because of loose material clogging the hole. Primers are prepared just before loading and usually are put into the hole after the second or third stick of explosive. At the Crystal-Victory mine the grades of explosives used are Trojan 40C and 60C nitrostarch powder in 1-1/4- by 8-inch and 1-1/8- by 8-inch cartridges, and at the No. 1 mine the grade of explosive used is Hercules Gelamite No. 1 in 1-1/4- by 8-inch and 1-1/8- by 8-inch cartridges. An average of 0.65 pounds of powder per foot of hole is used to load the blast round. No stemming is used, but the powder is well tamped to within 18 inches of the collar of the hole. At the end of the shift the miner fires the round with a hot-wire-fuse lighter in the sequence shown in figures 6 and 7. The average round will break 125 to 180 tons of ore, depending on the depth of the round and the height of the face.

The initial extraction of an ore body may range from 65 to 70 percent, and a final extraction of 90 percent or better can be anticipated. Mine conditions may change these figures but on the average they can be considered as general for the mine. Under present mining methods a dilution of not more than 25 percent of waste rock, based on an average ore thickness of 9 feet, is a fair estimate.

One of the two types of drilling jumbos currently used at the company mines consists of a drilling jib mounted on a company-designed, self-propelled, rubber-tired, four-wheel chassis. A single Joy hydraulic jib carries a Cleveland drifter model D-25 drill with an air-driven chain feed mounted on a 10-foot sash. The drifter has a 3-1/2-inch bore and is chucked to take 1-1/4-inch-round lugged steel. The motor drives a chain feed, which controls the movement of the drill. A hand-operated hydraulic pump on the truck bed supplies power for the vertical and horizontal motion of the jib. This jumbo is self-propelled through a transmission driven by a 5-hp. 440-volt motor with a V-belt connection. The drilling rig is well balanced and held stationary when drilling by putting the machine in gear.

The other unit, used only at the No. 1 mine, is a Gardner-Denver mobile duplex jumbo, which has two Joy T-350 drifters mounted on 12-foot chain-feed sashes. They are chucked to take 1-1/4-inch-round lugged-shank steel. The movements of the jibs and drills are controlled by central valves, and hydraulic power is supplied by an air-driven hydraulic pump. One miner and a helper operate this machine. (See fig. 8.)

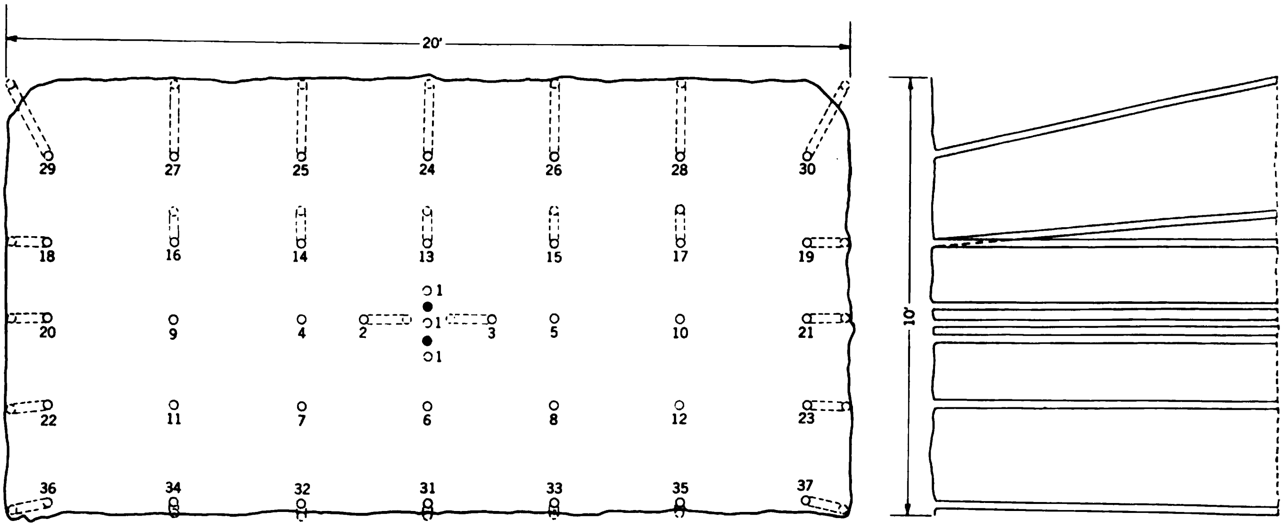
Several airleg percussion drills are used in the mines because of their versatility and flexibility. (See fig. 9.) They are used extensively in mining faces having vertical heights as much as 10 feet. The company prefers airleg drills because of their low initial and maintenance cost, their application to drifting, sinking, and blockholing, and their rapid setup time in stopes with a low back or uneven bottom. The use of this equipment makes it unnecessary to completely clean out the drift and grade the bottom, and such cleaning and grading are required when jumbo equipment is used. Although these drills have many applications they will not totally replace jumbo units,



Numbers indicate order of firing
2 8-hole round, using a 2-drill jumbo

Holes 11' deep

FIGURE 6. - Stope-Face Round at Minerva No. 1 Mine.



Numbers indicate order of firing
3 1-hole round, using air-leg drills (2)
● Open holes

Holes 8' deep

FIGURE 7. - Stope-Face Round at Crystal-Victory Mine.

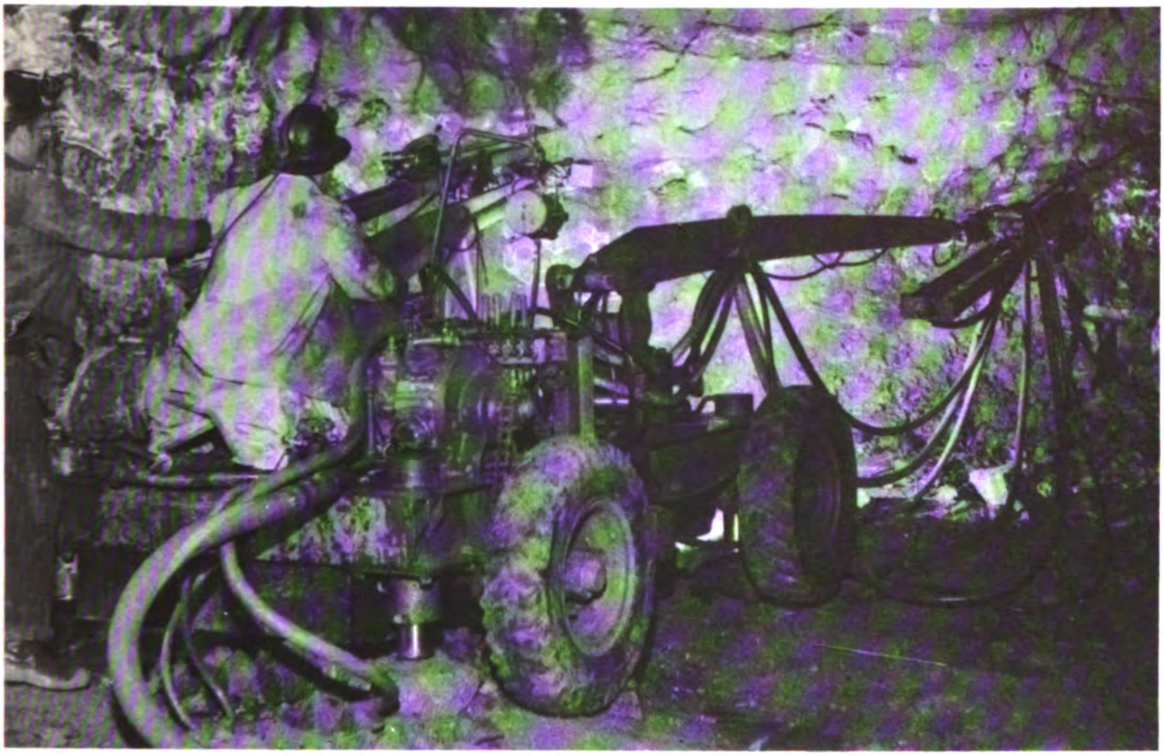


FIGURE 8. - Drill Jumbo Used at Minerva No. 1 Mine.

because each type has its own field of application. These machines are chucked to take 1-inch hexagonal, hollow, alloy drill steel, depending on the type of bit used. In most instances 48-inch feeds are used with the airleg drills, but occasionally 72-inch feeds with telescopic legs are used to drill in abnormally high places and to increase the length of the feed.

Three types of bits are used at these mines: A detachable four-point side-hole, "throwaway" bit; four-point socket-type, carbide insert bits; and carbide insert chisel bits. The latter type is purchased as an integral part of the drill steel. All tungsten carbide bits are sharpened at a central location at each mine by a portable air-powered grinder. Throwaway side-hole, knock-off bits are used for most production work and have given satisfactory performance. Although the penetration rate of the bit will vary with the hardness of the material drilled, the throwaway bit will average 1 foot per minute in the ore horizon. Development work has proved that the best drilling results were obtained when using four-point socket-type carbide-insert bits in sandstone and chisel-type carbide-insert bits in limestone. The four-point carbide-insert bits have been used extensively to drill roof-bolt holes in predominantly sandstone beds.

Loading

The development of mechanical loading at these mines resulted from a free exchange of information between the operators in the flourspar district and others outside the district with similar operating problems.

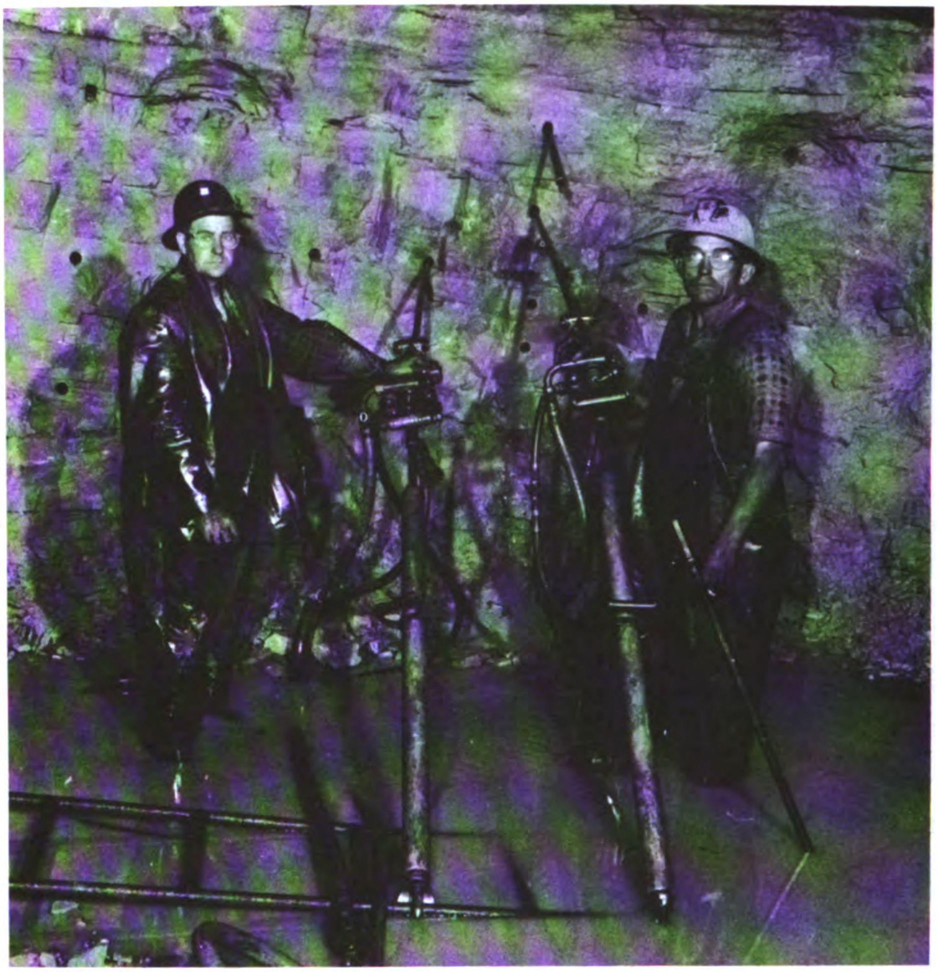


FIGURE 9. - Typical Airleg Drill Used at Crystal-Victory Mine.

Formerly, loading was done by hand mucking and later by track-mounted rocker-type equipment that required rail haulage facilities. Transition to the present trackless loading and haulage units involved large investments to replace equipment that was still capable of meeting normal production demands.

When considering the changes necessary in converting track-loading and haulage equipment to trackless units, the company considered the tonnage to be handled in a given period, power availability, and the estimated initial and maintenance costs. The larger capacity and greater flexibility of trackless units indicated a probable lower operating cost and investment per unit of capacity and were the influencing factors of choice.

In the present trackless method, broken ore is loaded mainly by slusher ramp loaders and, to a lesser extent, by crawler or rubber-tire-mounted end loaders.

The slusher loader unit consists of either a crawler or a rubber-tire-mounted chassis, a steel ramp, a 20- or 30-hp. Ingersoll Rand three-drum electric slusher and a 42-inch scraper. These units are highly maneuverable because each track or set of wheels is independently controlled and powered by a 15-hp. electric-gear motor, which transmits power through sprockets and chain drives. The steel ramps are 60 inches wide. A small, dry transformer is mounted on a portable ramp to reduce 440 volts to 220-110 volts and to supply power to sealed-beam lights, which are used in the slushing area. The steel ramp is mounted over and integrated with the chassis by structural-steel supports; the bottom of the ramp is inclined at an angle of approximately 24°.

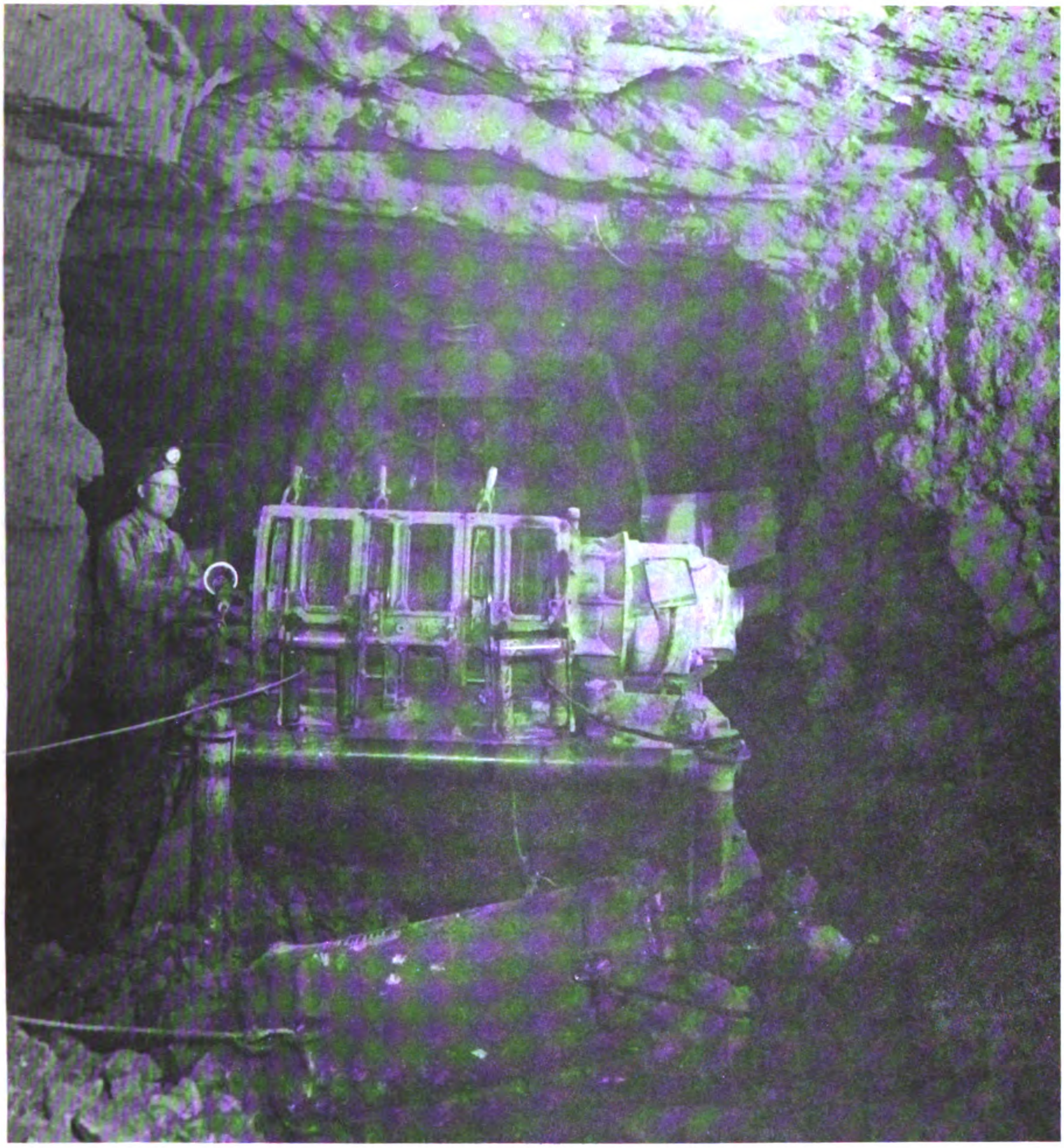


FIGURE 10. - Typical Loading Ramp Mounted on Crawler Chassis.

The three-drum slusher unit, which moves the scraper by means of a control pull drum and two tail rope drums, is mounted at the forward end of the unit over the throat of the slide. Controls of the slusher are located conveniently on one side of the machine, which allows a greater margin of safety and permits operating in areas with low headroom. The tail ropes from the slusher hoist are passed through a sheave wheel anchored to the tail boom of the unit, over the opening, and passed by the idler rollers at the throat of the unit and then attached to the scraper. The wire rope on all three slusher drums is preformed improved plow steel, one-half inch in diameter constructed of 3 strands having 19 wires per strand. (See figs. 10 and 11.)

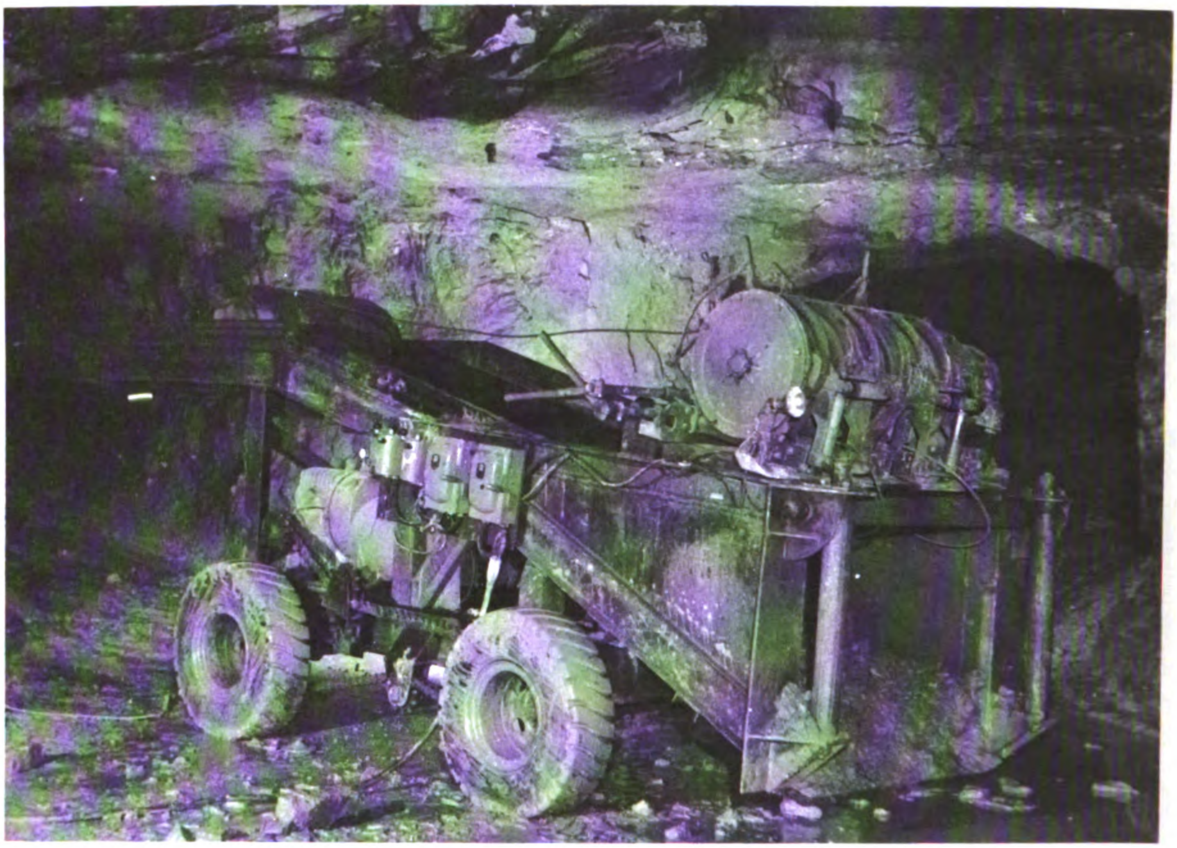


FIGURE 11. - Typical Loading Ramp Mounted on Rubber-Tire Chassis.

The slusher loader has the unique ability to extend its loading range into areas where relatively thin seams of ore are mined without increasing the dilution of ore with waste rock. Dilution normally would be required when making room for other types of loading units. The unit also has the advantage of extending its normal slushing range from 25 to 150 feet without too great a loss of efficiency. The need for extending the range to these limits would apply to areas having unusually irregular floors, inclinations too great for truck and end-loader travel, or places with inadequate space for maneuvering other types of loading equipment. This type of loader also provides a safe method of mechanical loading when extracting stope pillars by allowing the workers to remain out of the area of unsupported roof. This can be accomplished by setting up the machine in a protected area outside the immediate zone of pillar extraction.

The slushing ramp is moved into position at the beginning of a loading cycle, and the rear end of the chassis is raised on blocks, which elevates the tail boom and lowers the throat lip. Tracks or wheels (depending on which type of unit is used) are blocked to anchor the unit into position. After the tail-rope sheaves are hung, the scraping operation is begun. In the loading cycle the scraper brings the ore to the throat of the ramp, moves it up the inclined bottom, and passes it through an opening in the tail boom into trucks positioned behind the machine. The slushing area is well lighted by two

150-watt sealed-beam bulbs to aid the slusherman in his operation and improve safety. The trucks are normally backed up to the unit for best results. While waiting for a truck to return, the operator of the unit will normally scrape the broken ore closer to the ramp for greater speed in loading.

Front-end loaders are used to supplement slusher loaders at both mining operations if loading conditions are favorable. At the Crystal-Victory mine two Allis Chalmers Hi-lifts, model HD-5, 1-1/4-yard-capacity, front-end-dump crawler-mounted loaders are used; at the No. 1 mine a 1-1/2-yard Hough Model, HMD Payloader is employed. The Payloader is equipped with a four-wheel drive and a 99-hp. Hercules, model DJXH diesel engine. High-pressure tires were replaced with medium-pressure tires to obtain better service on a rough floor.

Although excellent results have been obtained with this type of loader in moving surface stockpiles, underground service is limited because of extremely high maintenance costs due to unfavorable operating conditions. Factors such as uneven floors, large sharp-edged broken-rock fragments, and too little room to manuever in certain working areas are detrimental. During the normal course of mining the greatest single advantage is its ability to be moved on short notice. The end loader is also employed extensively for cleanup work and for grading to allow truck haulage to the faces.

Transportation

The basic reasons previously given for adopting current loading equipment also applies to hauling equipment. This relationship exists because one operation cannot change drastically without affecting the other. In a featured article by Montgomery[8] emphasis is placed on the conditions required to successfully adopt and profit from truck haulage underground:

> Where height and ventilation is adequate, trucks have shown themselves to be a most economical mode of short haul transportation, and, in many cases, can compete with rail or belt-conveyor haulage in instances where indicated mine-life is short, the daily ore requirements small, or the haulage gradients and directions complex.
>
> They are ideal from the standpoint of maximum flexibility of utilization over a wide mining area, and are the best conveyances to serve in areas where mobile drill-jumbos and mobile trackless loading machines of all kinds are the rule.

Since diesel-truck roads could follow the dips of the ore up to 15-percent inclines and could spiral down to underlying bedded ore levels, truck haulage was selected as the method best suited for recovery of the remaining ore reserves at the Crystal-Victory and adjacent mines and at the Minerva No. 1 mine.

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[8] Montgomery, Gill, Auto Trucks Underground: Min. Cong. Jour. vol. 42, No. 11, November 1956, pp. 42-44.

The efficient use of diesel-powered trucks in a flat-lying deposit requires proper ventilation and maintenance of large haulage and loading drifts. Because of clearance requirements, a greater quantity of waste must be mined occasionally when ore beds of thicknesses less than minimum drift height are encountered. This disadvantage is more than offset by the flexibility of a loading and haulage system when using diesel-powered trucks.

At the Minerva No. 1 and Crystal-Victory mines all the ore is hauled by trucks that have been modified considerably to meet the demands of underground haulage. The company had favored the purchase of used standard 2- and 3-ton (nominal load rating) dump trucks; gasoline motors were replaced by Hercules, model DOOD, 79-hp. diesel engines, with the main frames reinforced, heavy-duty springs added, and the beds strengthened. These trucks hauled payloads ranging from 10,000 to 11,000 pounds of ore per trip.

However, a study in 1957 of mine truck performance at the Crystal-Victory mine showed that haulage efficiency and costs could be reduced substantially by using trucks of heavier construction and higher horsepower for the mine haulage system. During the testing period load capacity, fuel consumption, and maintenance requirements for each truck were observed and recorded. On the basis of this study, the company decided to purchase several new trucks, each with a nominal load rating of 3 tons and a 127-hp. diesel engine, which would haul an average load of 13,000 pounds. It is planned eventually to replace all reconditioned units with the same new model to assure standardization of haulage equipment.

These trucks are GMC model 660 with a 141-inch wheel base, fitted with a 4-71 diesel engine, a 5-speed transmission (direct in fifth speed), and a double-reduction rear axle, which has a 22,000-pound rating, a gear ratio of 7.3:1 and 9 by 12 twelve-ply-rating truck-lug nylon tires. The trucks are purchased with reinforced frames and Hercules model 100 hoists of 11-ton capacity. The dump bodies are constructed locally. (See fig. 12.)

The study indicated that an efficient truck-haulage system requires (1) standardization of equipment, (2) a preventive maintenance schedule, (3) an established, reliable, and well-stocked source of supply of all spare parts, and (4) full utilization of equipment. The study also indicated a desirable ratio of vehicle weight to payload of 1:1 and an engine rating of 20 hp. per payload ton. An effort was made to establish a hauling cycle that will balance with loading operations. Under normal mining conditions a slusher ramp will load approximately 200 tons a shift. Two to four trucks are required, depending on haulage distance, to service the loading unit. The mine operators aim to create a production unit consisting of two drilling crews, a slushing ramp, and two to four trucks. Drilling, loading, and haulage within the unit are balanced in such a way as to best utilize the equipment.

In the Crystal-Victory mine, ore is hauled approximately three-fourths of a mile over underground roads having grades as much as 15 percent against the load before reaching the portals of one of three surface adits. From the adits the trucks travel over surface roads having grades of 2 to 12 percent against the load to the Crystal mill primary crusher station.

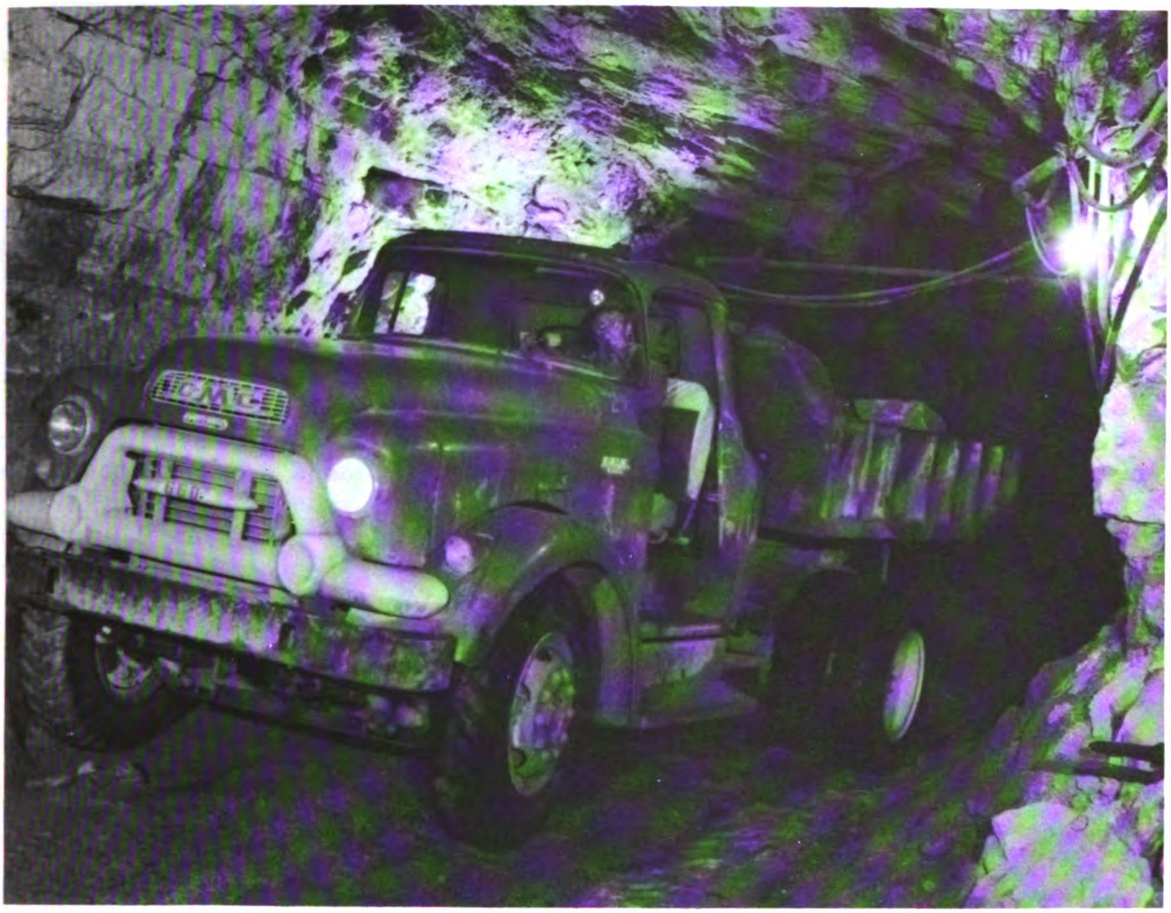

FIGURE 12. - Typical Haulage Truck Used Underground.

From the Minerva No. 1 mine production faces, the trucks transport ore on underground roads for half a mile at grades up to 6 percent against the load to the No. 1 shaft-bottom crusher station.

Before February 1957 a combination truck and belt haulage system was used at Mine No. 1. Trucks hauled the crude ore to a feeder installation at the head of a 30-inch main haulage-belt conveyor.

Before the changeover, two trucks were used in the haulage cycle, and a third truck was ready if a breakdown occurred. The load was hauled approximately 850 feet and dumped into a crusher circuit consisting of a hopper, pan feeder, and crusher. This crusher reduced and passed ore of minus-3-inch size directly onto a 30-inch conveyor belt. The belt carried the ore 1,700 feet at a load speed of 200 f.p.m. into a 200-ton ore-storage pocket at the No. 1 shaft.

Due to lack of flexibility and high maintenance costs in handling small tonnages the truck-belt system was discarded.

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Although there is systematic maintenance of underground haulage roads, the operating conditions for underground haulage trucks are invariably severe. Frequent travel over rough surfaces through standing water, and on steep slopes in the vicinity of production faces causes more than normal failure and wear to springs, axles, brakes, drive elements, and tires.

Exhaust-fume scrubbers are used to condition the exhaust gases of diesel engines. A carbon monoxide detector is frequently used to check the concentration of carbon monoxide in all underground diesel exhaust gases.

At the Minerva No. 1 mine crushed ore from the 200-ton main shaft skip pocket is loaded into two 3-ton-capacity Kimberly-type skips through manually controlled, air-powered gates and chutes. The skips weigh 5.5 tons when fully loaded. They are hoisted in balance from the 630-foot-level loading station at an average speed of 600 f.p.m. to automatic skip dumps located above the 200-ton surface ore bin. The main shaft hoist is a Lambert single cylindrical drum unit; the drum has a diameter of 72 inches and a smooth face 54 inches wide. It spools two (one overwind and one underwind) 1-inch-diameter, 6- by 19-wire-per-strand ropes of preformed improved plow steel. The hoist is driven with reduction gearing by a 150-hp. wound-rotor induction motor. All hoist controls are operated manually.

Ore hoisting is normally confined to the day shift only. The hoisting equipment has a rated production of 80 tons per hour. The skips and hoist are also used for transporting men and materials into and from the mine on both the day and evening shifts.

The main shaft headframe is a structure 80 feet high, which was completely fabricated at the mine from 4-inch API rotary drill pipe. The three vertical sections were built on the ground and hoisted into position, and the headframe joint connections and horizontal bracing were electric welded.

The 200-ton surface ore bin is adjacent to and supported partly by the headframe but is mostly on supports separate from the headframe. The bin was fabricated from structural-steel members and plates and divided into two compartments--one of 150-ton and the other of 50-ton capacity. The larger bin compartment serves as storage for mill feed; the smaller one is usually used for waste, but it can be used for temporary storage of ore when production is excessive or the mill is down for repairs.

The 50-ton bin compartment is located next to the skip dumping knuckle. Its top is covered by a sheet-metal door, which serves as a chute to the larger bin compartment. Thus, when ore is being hoisted the door is closed and the ore is directed to the 150-ton bin compartment. When either waste or stockpile ore is hoisted, the door is opened and the rock material goes directly to the smaller bin. The door is operated by a small electric winch. Figure 13 illustrates how the waste or ore is drawn from the 50-ton bin compartment into dump trucks through an air-operated chute gate and is hauled to waste dumps or the surface stockpile.

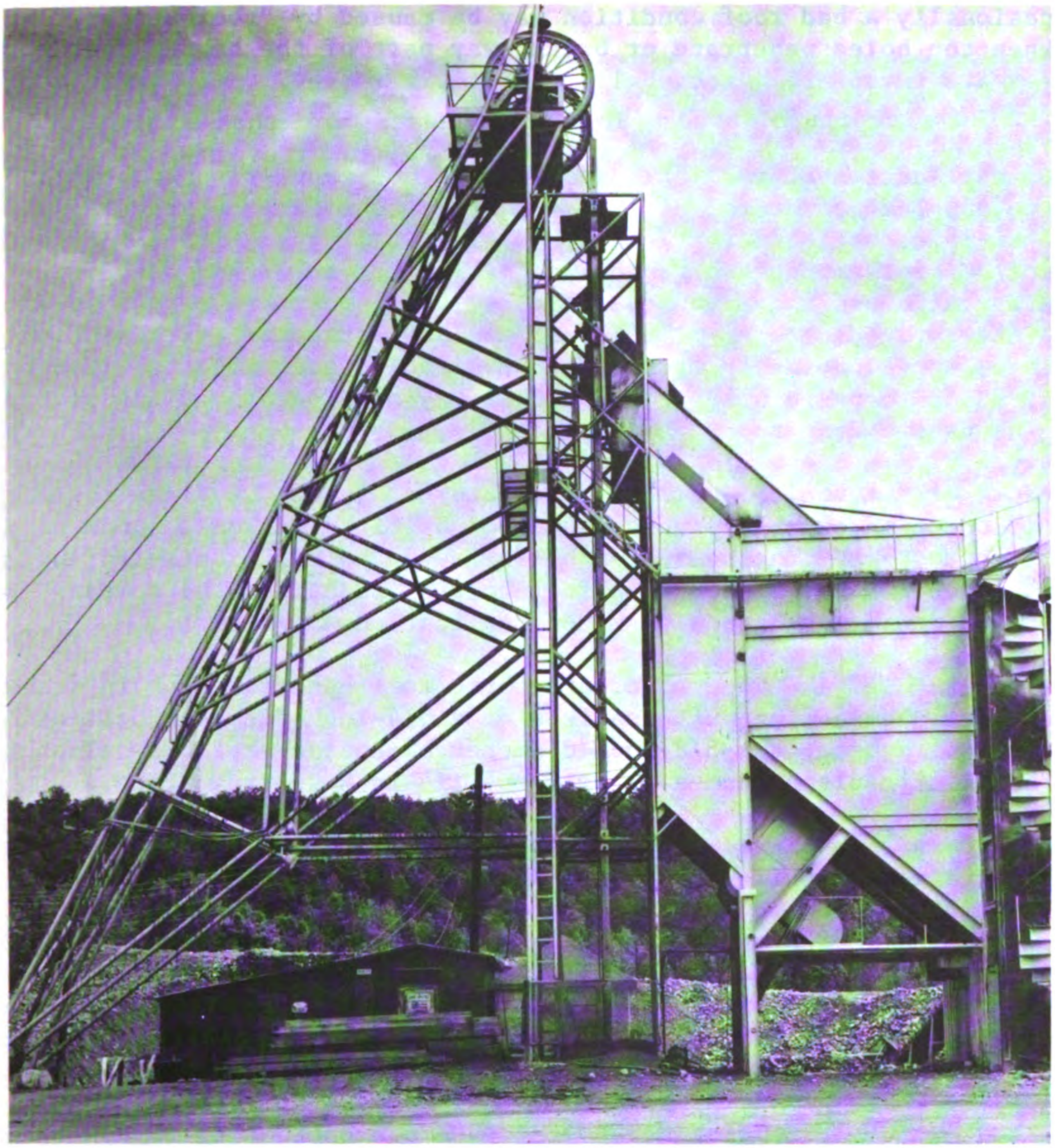

FIGURE 13. - Minerva No. 1 Mine Headframe and Integrated Ore and Waste Bin.

Roof Support

The capping of the ore horizons at the Crystal-Victory mine is either the Rosiclare sandstone or Fredonia limestone; at the Minerva No. 1 mine the ore bodies are overlain by Bethel sandstone. All the roof rock beds are sturdy and generally capable of standing over open spans of as much as 30 feet between pillars. However, if the base of a roof contains a sandy shale or is fractured, or crossbedded roof conditions are encountered, this span may be as little as 15 feet between pillars and require artificial support to allow enough operating clearance and satisfactory extraction.

Occasionally a bad roof condition may be caused by "roofburning," which occurs when top holes penetrate or break away part of the bedded roof rock. Such areas are immediately roof bolted to stabilize the roof rock adjacent to the hole.

The introduction of roof bolts as a method of supporting weak roof and as a means to supplement natural pillar support is considered a great asset to mining flat-lying ore bodies. This is particularly true at the Minerva No. 1 and Crystal-Victory mines, where the roof is bolted to within 4 to 5 feet of the working face when conditions warrant it. Roof bolts have been used to increase safety, the rate of mining, and the percentage of extraction of minable ore. Drill holes to accommodate roof bolts have also provided other benefits, as ore occasionally is found that may be hidden by slips of barren rock at the base of the roof.

Because of the variable amount of fractures, joints, and shale seams that frequently occur in an area of proposed roof bolting, personal judgment is necessary to determine the number of bolts needed to efficiently strengthen weak structures. However, for most roof-bolting practices the company follows procedures presented in Bureau of Mines publications.[9] [10]

Roof bolts used in these mines are three-fourths of an inch in diameter and 4 to 8 feet long. The unit consists of a 3/4-inch-diameter bolt with a 1-1/8-inch square head, a 1-3/8-inch-diameter expansion shell, a palnut to hold this shell in place, and a 4- by 4- by 1/4-inch bearing plate.

When the roof is pinned with bolts, a platform is often necessary to reach the high roof required in present mining methods. Therefore, it is common practice to use end loaders, mine trucks, and jumbo booms for the needed platforms from which roof bolts can be properly placed and secured. (See fig. 14.) The roof bolter is wholly responsible for drilling the proper length of hole to obtain proper bolt anchorage. When using expansion shells, the depth of the hole is not critical as long as firm rock is reached to anchor the bolt in place. No more than 12 inches of firm ground is needed to secure the roof bolt properly, and in most instances the roof bolter can tell when he has obtained this distance by the rate of penetration of his bit and by examining the physical nature of the cuttings. The holes are drilled with 1-1/2-inch-diameter bits, which are discarded when worn to 1-3/8-inch diameter.

The roof bolts are secured and tightened by means of a Chicago Pneumatic, model RP-365, air-powered impact wrench. To obtain proper bolt tension, the miner watches the bearing plate and notices when it begins to form against the rock; he then observes the operation of the air-operated impact wrench, which looses speed as the bolt is brought to proper tension. Periodically, the

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9/ Panek, L. A., Design of Bolting Systems to Reinforce Bedded Mine Roof: Bureau of Mines Rept. of Investigations 5155, 1956, 16 pp.

10/ Barry, A. J., Panek, L. A., and McCormick, J. A., Use of Torque Wrench to Determine Load in Roof Bolts: Bureau of Mines Rept. of Investigations 5080, 1954, 17 pp.

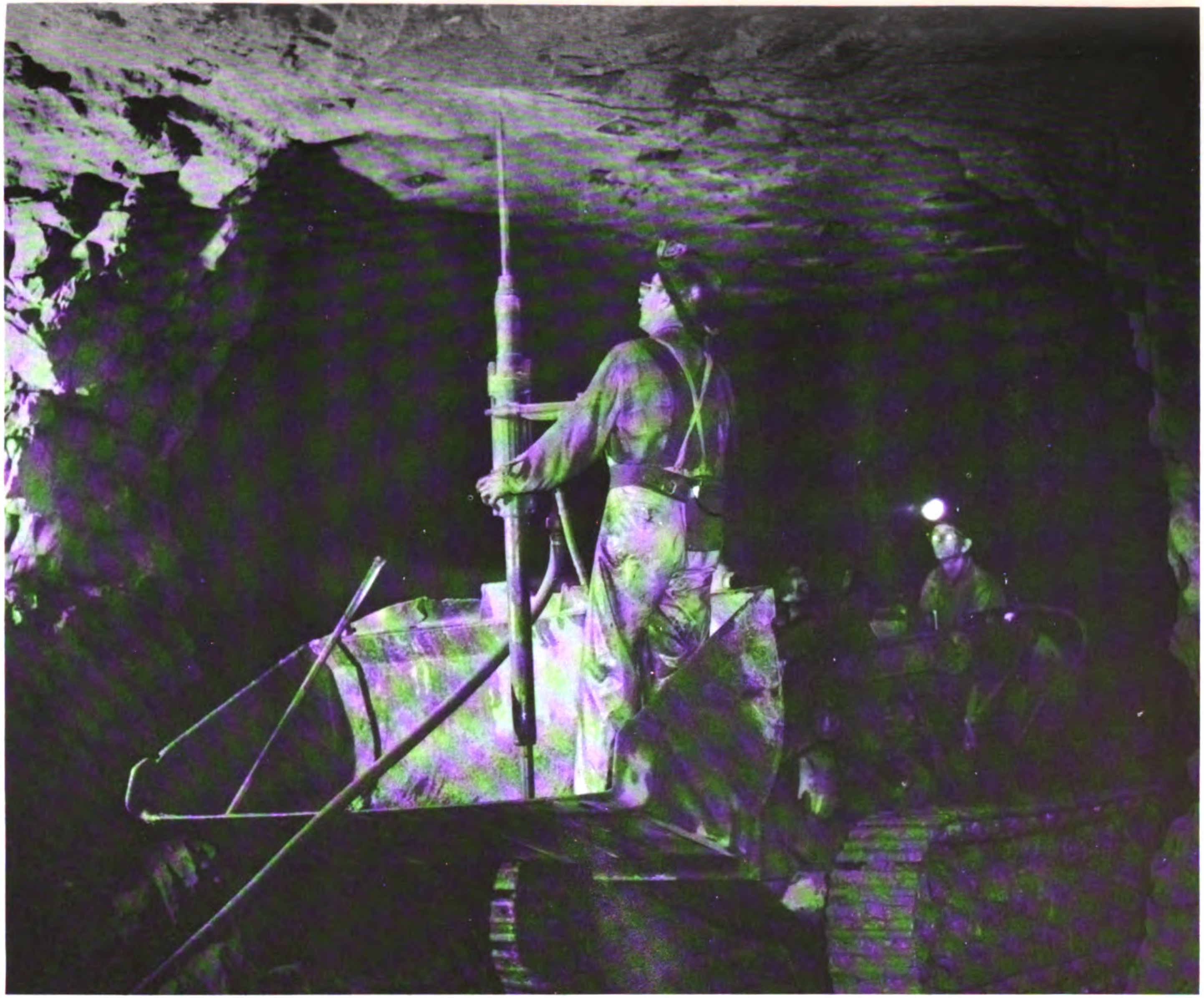

FIGURE 14. - Typical Roof-Bolting Operation.

mining engineer will spot-check 10 bolts at random with a torque wrench. The torque required to tighten well-placed bolts ranges from 170 to 200 foot-pounds.

Roof-bolt recovery is practiced only when final extraction is made in certain areas.

AUXILIARY OPERATIONS

Primary Crushing

Haulage trucks at the Minerva No. 1 mine deliver ore from production faces to an underground crusher installation located above the 200-ton main shaft-skip loading pocket. The trucks end-dump the loads directly into a 10-ton steel hopper mounted over a Universal 36-inch-wide, 9-foot-long, 12-bar, 9-inch pitch Wobbler feeder. This feeder is set to pass all minus-3-inch material, which drops directly into the skip loading pocket, and discharges all plus-3-inch material to a Pioneer 15- by 36-inch jaw crusher, with a discharge opening of 4 inches. The crushed ore drops directly into the skip loading pocket. The feeder is driven at 9 r.p.m. by a 15-hp. gearhead motor through a set of sprockets and a roller chain. The crusher is driven at 240 r.p.m. by a 50-hp. electric motor through a V-belt drive. The crusher and feeder controls are electrically interlocked so that the crusher must be running before the feeder can operate. The unit handles up to 120 tons per hour, which is almost double the actual requirement. This installation is equipped with a 10- by 20-foot bypass grizzly, with 10-inch-square openings. If the crusher or feeder fails, the haulage trucks can use an alternate drift to reach this grizzly and dump onto it. The material passing the grizzly drops directly to the shaft skip pocket.

Primary crushing at the Crystal-Victory mine is done at a surface hopper-feeder-crusher installation located at the upper end of the Crystal milling plant on a hillside overlooking the plant. (See fig. 15.) Haulage trucks deliver ore from the underground production faces or from surface stockpiles to a 10-ton steel hopper set over a United heavy-duty 30-inch by 14-foot pan feeder. The feeder is driven by a 5-hp. electric motor through a variable-speed transmission and a gear reducer at a normal speed of 5 f.p.m. The material discharged from the feeder passes over an inclined 30-inch by 4-foot grizzly, with rails spread at 2 inches. Undersize material drops through the grizzly onto a 30-inch conveyor belt. The grizzly oversize is fed to a Telsmith 32- by 20-inch jaw crusher, which has a discharge opening of 3 inches It is driven at 250 r.p.m. by a 50-hp. electric motor through a V-belt drive. The crushed ore drops onto the 30-inch conveyor belt and is delivered, with the minus-2-inch ore, to a 200-ton coarse-ore bin at the head of the mill. This primary crushing installation is rated at a capacity of 150 tons per hour. A Transweigh electric, continuous belt-scale on the latter belt records the feed rate and cumulative tonnage on a recording chart in the mill office.

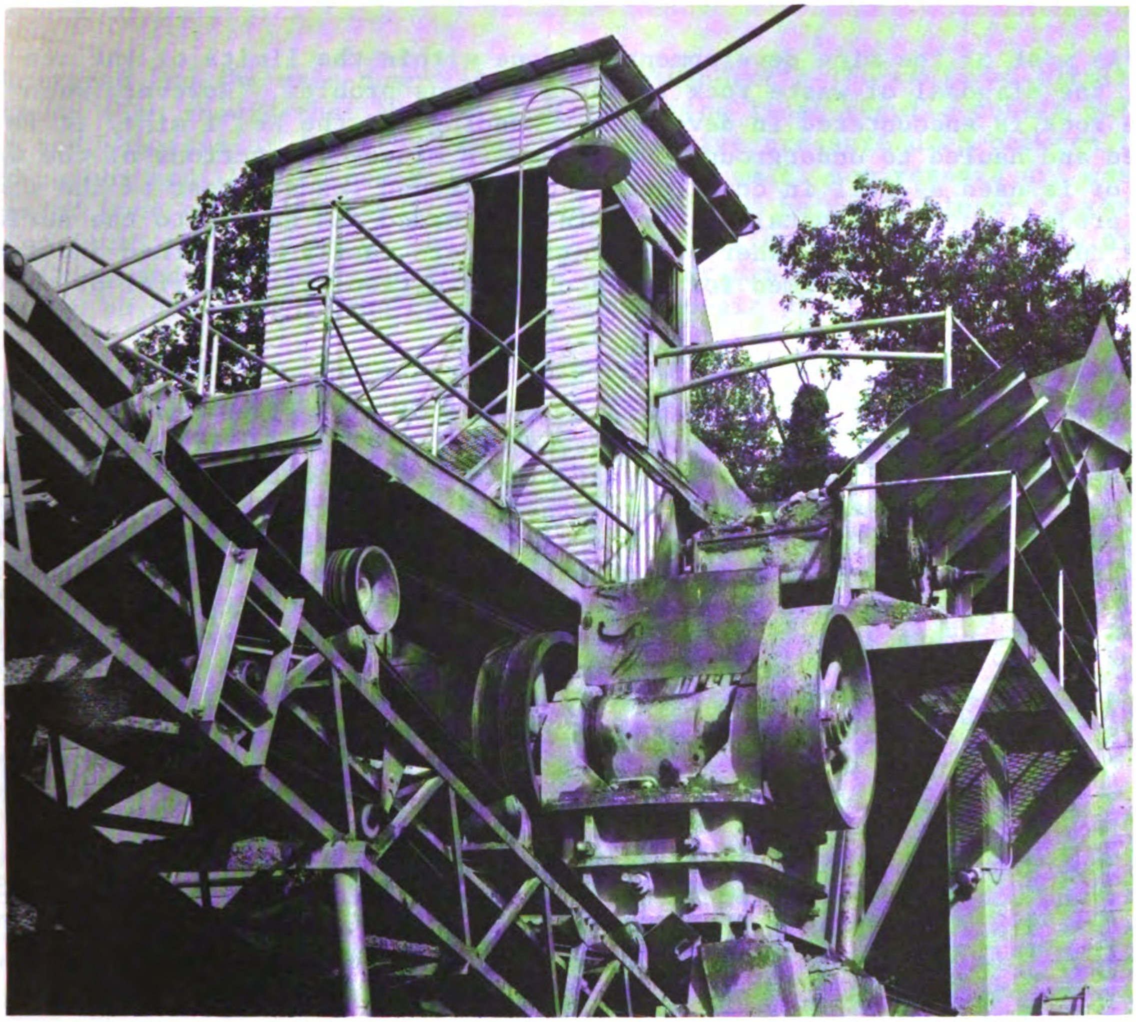

FIGURE 15. - Crystal-Victory Primary Crusher-Feeder Installation.

Ore Stockpiling and Waste Disposal

The surface stockpiling of mine ore is practiced at both Minerva Oil Co. mines. Stockpiling is necessary for a number of reasons. Among the more important are: (1) Providing enough ore to operate the mill 7 days a week with ore production from mines that operate 5 days a week; (2) the beneficial effect on mill products and recoveries when the feed from various mining areas is blended and stabilized; and (3) providing a surge pile, which makes mining and milling operations independent of each other for short periods.

Stockpiles are at specified and prepared sites close to the Crystal and Minerva mills. The ore is transferred from the piles to the mill by 1-1/2-yard rubber-tired end loaders and gasoline-powered dump trucks. The quantities of ore stored in stockpiles vary, depending on the balance between mine production and milling rate. A minimum stockpile of at least 1 week's supply of ore for the mill is considered adequate.

As most of the mine development is done within the limits of the ore body, the disposal of waste rock is not a serious problem. However, when waste rock is encountered in development headings at the No. 1 mine, it is loaded and hauled to underground dump areas in mined-out sections of the workings or is used as fill in constructing underground roads. Most of the waste rock produced at the Crystal-Victory mine is loaded and hauled to the surface waste dumps on hillsides, where dump surfaces are easily maintained and from which waste may be reclaimed for surface construction fill material or sold.

Powder Storage

Surface magazines for the separate storage of explosives and detonators are maintained at each mine by the Minerva Oil Co. These structures conform to the provisions of the Illinois metal-mining code, and annual permits are issued by the Department of Mines and Minerals authorizing their operation. The fuse is prepared for blasting in a separate building, and only enough to provide for daily blasting requirements is transported underground. The prepared fuses are taken into the mine immediately before loading the blastholes. Underground storage areas for explosives are used at both mines. Small magazines generally are located in dry, deadend drifts, which are walled-off, locked, and provided with protective signs and lights. A maximum quantity of powder, enough for 48 hours, is allowed in these underground magazines.

Service Shops

Underground shops for routine maintenance and repair work on haulage trucks and other mining equipment are maintained in each mine. These shop areas are close to mining and haulage operations and are well lighted and equipped. Diesel-powered service trucks, carrying welding equipment and supplies, are stationed at the repair shop in each mine.

All overhaul and machine-shop repair work is done on the surface in well-equipped mechanical and electrical shops at each property.

Drill steel is prepared and reclaimed in a central drill-steel shop at the Crystal-Victory mine. This shop has oil-fired heating furnaces, an Ingersoll-Rand, model 54, drill-steel sharpener, shank and bit grinders, and quenching baths. Due to the use of detachable bits, the work done in this shop is limited to shanking lugged and collar steels and forming pin ends on rods for the use of detachable bits. Tungsten carbide-tipped drill steels and bits are sharpened at a central underground location in each mine.

COMPRESSOR PLANTS

The method of supplying compressed air for mining operations at the Minerva Oil Co. mines is presently in a transitional stage. Centrally located main compressor plants, with extensive distribution lines, are being replaced by a number of smaller capacity portable "spot" compressors installed in the mines at or close to principal points of air consumption. Studies of the compressed-air supply plant and distribution systems indicated that a considerable saving in cost could be accomplished, if the transmission pipelines could be shortened and the main compressor-plant attendant's job could be eliminated. The study also showed that extensive distribution lines require costly maintenance and, because of friction, cause an excessive pressure drop between the air receiver and the air-powered equipment. The small compressors are easily relocated when operating conditions require them to be moved closer to the working faces of any part of the mine. This practice provides a degree of flexibility and efficiency to the compressed-air distribution system that could not be obtained by the central compressed-air plant.

The changeover to portable compressors has been made at the Crystal-Victory mine. The mine now uses three Ingersoll-Rand type 40, 220-c.f.m., two-stage compressors, which are driven by 50-hp. electric motors as shown in figure 16. The compressor unit may be mounted on either a four-wheel, rubber-tired trailer or on a steel skid frame, and the air receiver on a steel skid frame. This permits rapid movement of the units in a short time with little effort. The receivers are 3 feet in diameter and are used in 8- and 10-foot lengths.

The compressor unit is normally within 300 feet of the production area. It is advanced periodically as mining progresses to provide rock drills with compressed air of 95 to 100 p.s.i. Rock drill performance has been considerably improved because of this practice.

A minimum amount of service is required to keep the units operating at maximum efficiency. They are inspected at the beginning of each shift to check the lubrication system and to drain accumulated water from the air receiver and intercooler. Mine mechanics change the compressor lubricating oil and clean the oil-bath filters each week. Periodically, the compressor valves are cleaned and checked and an inspection made of the general condition of the unit.

Spot-type portable compressor units are being placed into service at the Minerva No. 1 mine. One unit is a Gardner-Denver WBK, 450-c.f.m. two-stage, compressor, driven by a 125-hp. electric motor. The motor and compressor are mounted on a steel skid frame. This unit is used to service the production area in the southwest end of the east ore-body stope. It delivers compressed air to a nearby 4-foot-diameter by 12-foot-long horizontal air receiver, mounted on a steel skid frame. Two Atlas COPCO CT-4, 195-c.f.m., two-stage air-cooled compressors, mounted on skid frames and driven by 50-hp. electric motors, are also in use at this mine. One of the units delivers compressed air to the equipment used in development headings, and the other, on the lower level at the Minerva No. 1 mine shaft, supplies compressed air for general use in the shaft area.

POWER PLANT

Electric power is purchased from the Southeastern Illinois Electric Cooperative; its 33,000-volt distribution line is located in the vicinity of both mines. Electric power to each property is transmitted by a company-owned 7,500-volt secondary line from a 33,000- 7,500-volt transformer station, where mine and mill power consumption is metered.

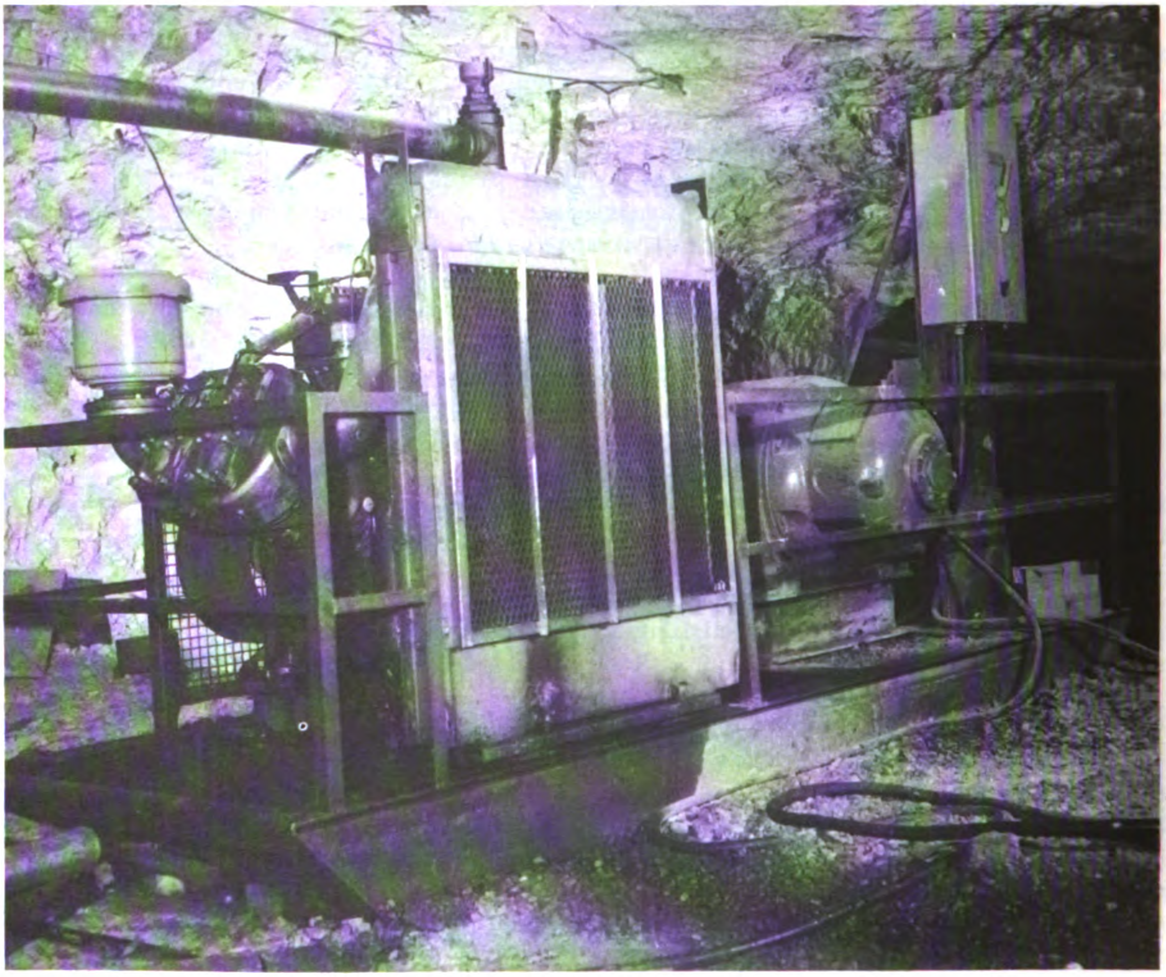

FIGURE 16. - Typical Mobile Compressor Installation.

At the Minerva No. 1 mine property the 7,500-volt secondary line is connected to a central 7,500- 2,300-volt transformer bank. Power for mine operations is transmitted by 2,300-volt surface lines to churn-drill holes, which bottom in the vicinity of the production areas. The 2,300-volt power is transmitted through No. 6 lead-sheathed cables, hung in these holes, to 2,300-440-volt transformer stations located close to compressor stations and other electrically powered equipment. The underground electrical equipment is operated at 440 volts, 3 phase, 60 cycle. Underground lighting circuits are operated at 110-120 volts; this voltage is provided at a number of points by 5-kv.-a., 440- 110-volt, single-phase transformers, which obtain electric power from the 440-volt mine circuits.

A central 7,500-volt secondary surface line traverses the Crystal-Victory property parallel to and approximately over the main NE-SW trend of the ore bodies. This line is connected to a number of skid-mounted semiportable 7,500-440-volt transformer banks, which are used to supply power for mining operations. (See fig. 17.) These banks, located at or near the collars of

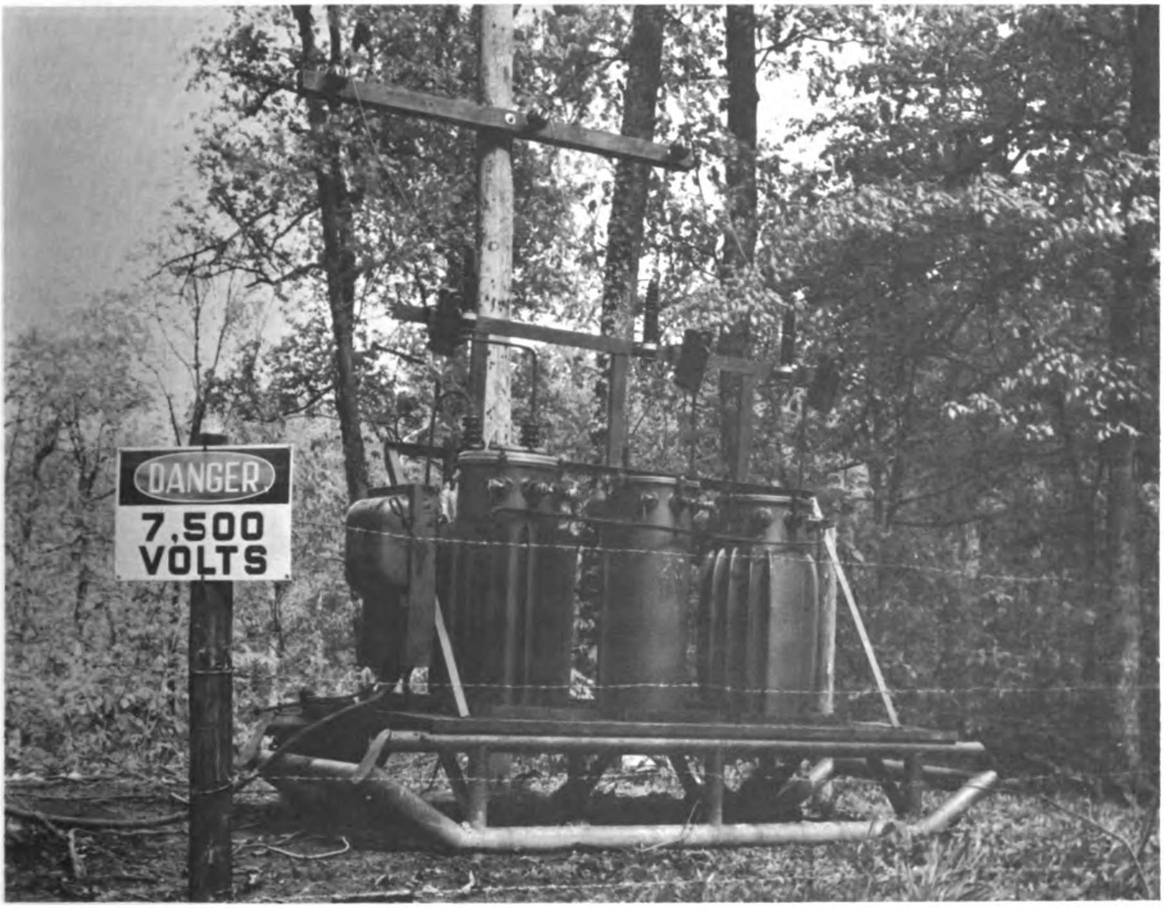

FIGURE 17. - Typical Mobile Transformer Bank.

churn-drill holes that bottom in production areas, are connected either directly from the 7,500-volt secondary line or from temporary stub-pole lines connected to the secondary line. Power is transmitted from these transformer banks into the mine, through the churn-drill holes, by heavy No. 2 rubber-covered feeder cables. Normally the feeder cables are connected to the fuse-type safety switches on temporary panel boards near the bottom of the holes. The various mine-power circuits are supplied from these panels. As mining progresses or as the location of the production faces are changed, the transformer banks, feeder cables, and temporary panels are moved to new positions.

The overall mining-power consumption per ton mined averages 14.2 kw.-hr. at the No. 1 mine and 12.3 kw.-hr. at the Crystal-Victory mine.

MINE VENTILATION

The primary ventilation circuit for the Minerva No. 1 mine consists of the controlled flow of air from the surface into the mine through a 5-1/2-foot-diameter air-service shaft. Figure 18 shows a low-pressure 4-foot Jeffrey Aerodyne Junior fan, installed at the collar of the air shaft, which circulates approximately 24,000 c.f.m. of air into the mine at a pressure

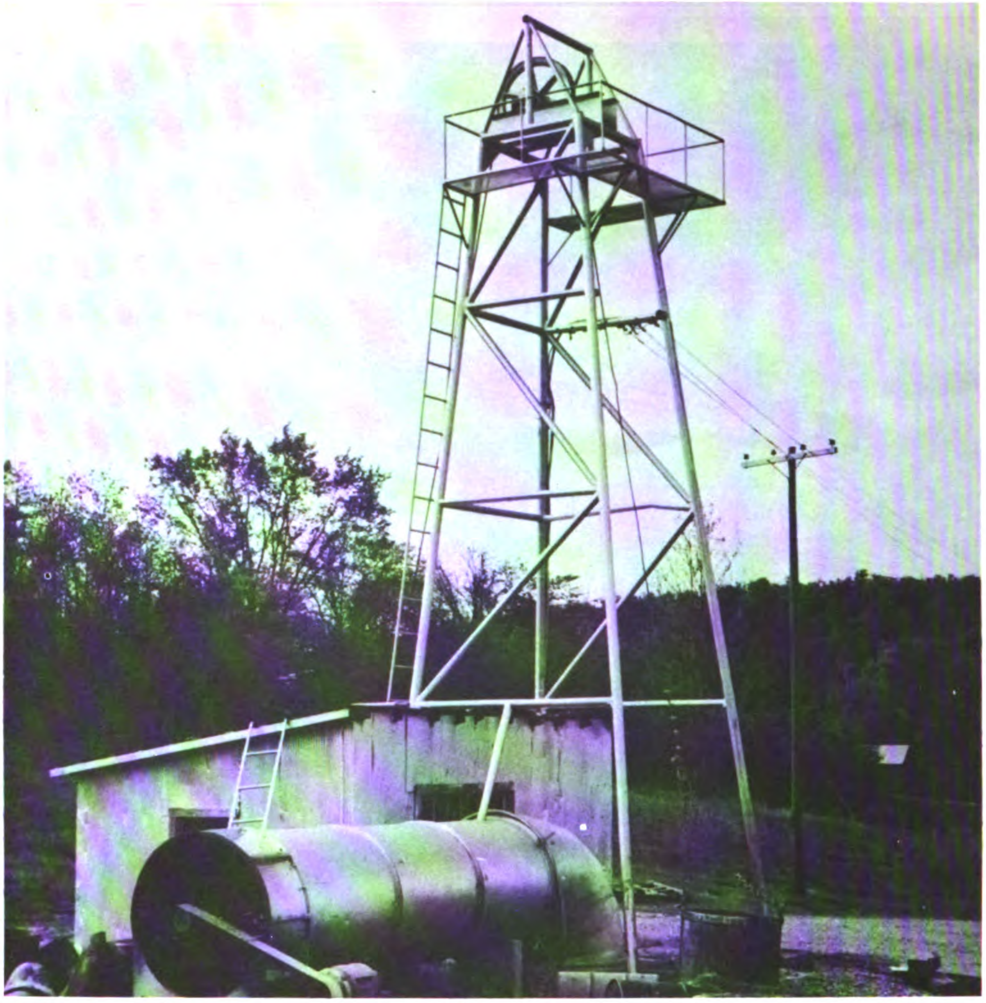

FIGURE 18. - Minerva No. 1 Mine Air-Shaft Fan Installation.

duty of 1-1/4-inch water gage. This fan is driven through a V-belt drive by a 15-hp. electric motor at 1,500 r.p.m. As the air enters the mine it flows through the main haulageways and interconnecting stopes and then exhausts from the mine through the main shaft, which is upcast. The main shaft is located between the east and west ore bodies, the air shaft is bottomed in the east ore body about 700 feet south of the main shaft. Both shafts are vertical. This ventilation system was considered adequate for production areas close to the main aircourses, but as the production faces were advanced away from the primary aircourses and as diesel-truck haulage was introduced, the problem of providing adequate air to the production faces became increasingly serious. The problem was partly alleviated when fresh air from the surface was forced into the mine through 6-1/2-inch drill holes, which bottomed in the production areas. The holes were drilled during the exploration program; however, only a few holes could be used for this service. A high-speed centrifugal blower, mounted at a churn drill hole, delivers 1,500 c.f.m. of air into the mine. At this rate of delivery, six to eight closely spaced holes would be required to provide an adequate quantity of air to the production faces. The high cost of drilling these holes prohibited this kind of auxiliary ventilation on a large scale when the mines began using diesel equipment underground.

Early in 1957 a ventilation survey of the mine showed that a satisfactory auxiliary ventilation system could be constructed, capable of delivering about 12,000 c.f.m. of air to either end of the east ore-body production areas. The basic plan required the use of a duct system to course air from the bottom of the air shaft to the production faces. Possible plans included a bratticed aircourse along the rib of the stope, small-diameter metal tubing with high-pressure blowers, large-diameter metal tubing with low-pressure blowers, or light, inexpensive plastic tubing, from which the company could fabricate its own type of duct.

The management decided to make a test trial of the plastic tubing because of its light weight, low cost, and flexibility. However, since no information was available concerning the fabrication, installation, and performance of this type of tubing, each step of its application was undertaken cautiously. The first step was to develop a method of fabrication at reasonable cost. Thereafter, the cost of installation, the ability of the tubing to withstand the required pressures, and the estimated life and maintenance costs were other factors to be considered and tested.

Before considering a method of fabrication, a study was made to select the largest diameter tube that could be installed in the stopes and haulageways without interfering with the mining operation. The company decided to fabricate a 54-inch duct, which was large enough to permit the use of low pressures and velocities to deliver the required quantities of air. The second stage of the test required the development of a method of fabrication. The first material tried was a 4-mil-thickness, clear polyethylene film, available in 16-foot widths. It was formed around 54-inch-diameter hoops made from 1-1/8-inch rough-sawn elm-wood strips. A locally constructed mandrel, 54 inches in diameter and 60 inches in length, was used to space the wooden hoops at 4-foot intervals. The polyethylene film was stapled to the hoops for stability, and the longitudinal seam sealed with 3-inch acetate tape, thereby forming a sealed tube. Two-inch acetate-tape strips were used to cover the film at the loop to give the tube added strength. The tube was fabricated in 100-foot sections by a two-man crew, which was able to assemble 150 feet of tubing each shift at a direct cost of $0.72 a foot. This cost included the polyethylene film at $0.30 a foot, hoops and connections at $0.16 a foot, tape and staples at $0.06 a foot, and labor at $0.20 a foot.

Approximately 1,200 feet of tubing was assembled and installed in the east ore body, extending from the air shaft to the southwest production area. A 48-inch propeller-type fan, operating at a boosted full-load speed of 1,500 r.p.m. by a 5-hp. motor, was placed in the end of the tubing adjacent to the air shaft. The fan has a pressure duty of 1/4-inch water gage, which increased to 1/2-inch water gage at full-load speed (1,100 to 1,500 r.p.m.). (See fig. 19.) The fan blew air from the shaft bottom and coursed it through the tubing. Figure 20 shows how the tubing was hung by wires attached to eyed screws and secured to opposite sides of each hoop. The ends of the 100-foot sections were butted together and secured by eyed screws and wire ties to make a tight joint. (See fig. 20.) Four men installed this tubing at a rate of 200 feet a shift at a cost of $0.38 a foot. Of this amount, supplies accounted for $0.08 a foot. The total direct cost for supplies, fabrication, and installation of this tubing was $1.10.

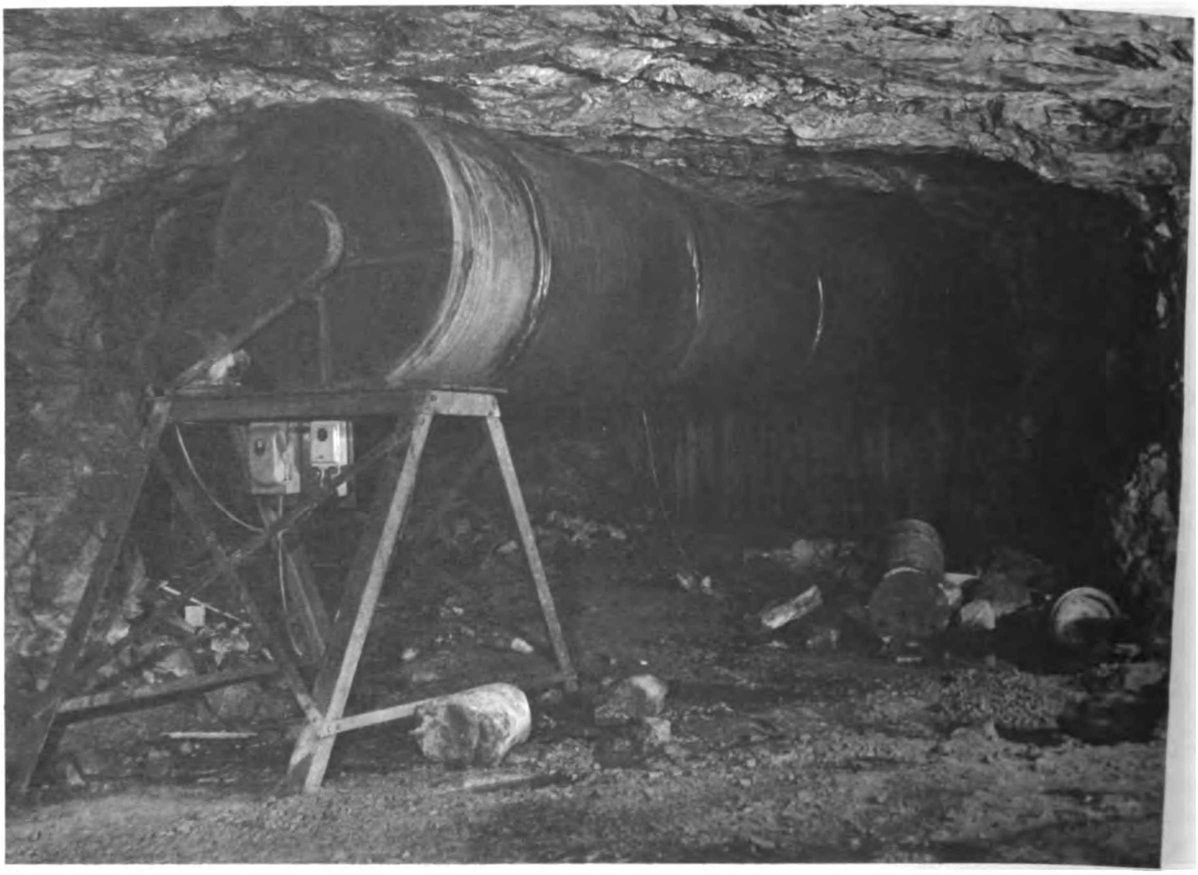

FIGURE 19. - Minerva No. 1 Mine Plastic-Tube Fan Installation.

This auxiliary ventilation system was operated for 6 months to test its efficiency. While conducting this test it was noted that high humidity in the mine caused the acetate tape to break its bond and permit failure of the longitudinal seam. Several attempts were made to use different brands of tape and seam coating; however, no satisfactory solution to the problem was found. The company therefore abandoned this method because of its high maintenance cost and subsequently decided to test a seamless tube of the polyethylene material. The company purchased 4 mil clear polyethylene tubing, 55-1/2 inches in diameter, and vinyl plastic tape. To avoid difficulty when placing hoops in long continuous tubing, the sections were reduced to 25-foot lengths. A mandrel, 54 inches in diameter and 10 feet long, was constructed by the company and used to place hoops in the tubing at intervals of 8 feet. The shaft of this mandrel was supported on movable pedestals, which provided ease in placing the polyethylene material and hoops on one end of the mandrel and removing the finished tubing from the other. Before removing the tube, 2-inch vinyl plastic tape was put around it at the hoops and stapled to give the duct stability. The cost to fabricate the seamless tubing was as follows:

Polyethylene tube............	$0.30
Hoops and connections........	.11
Tape and staples.............	.04
Labor........................	.12
Cost per foot.............	.57

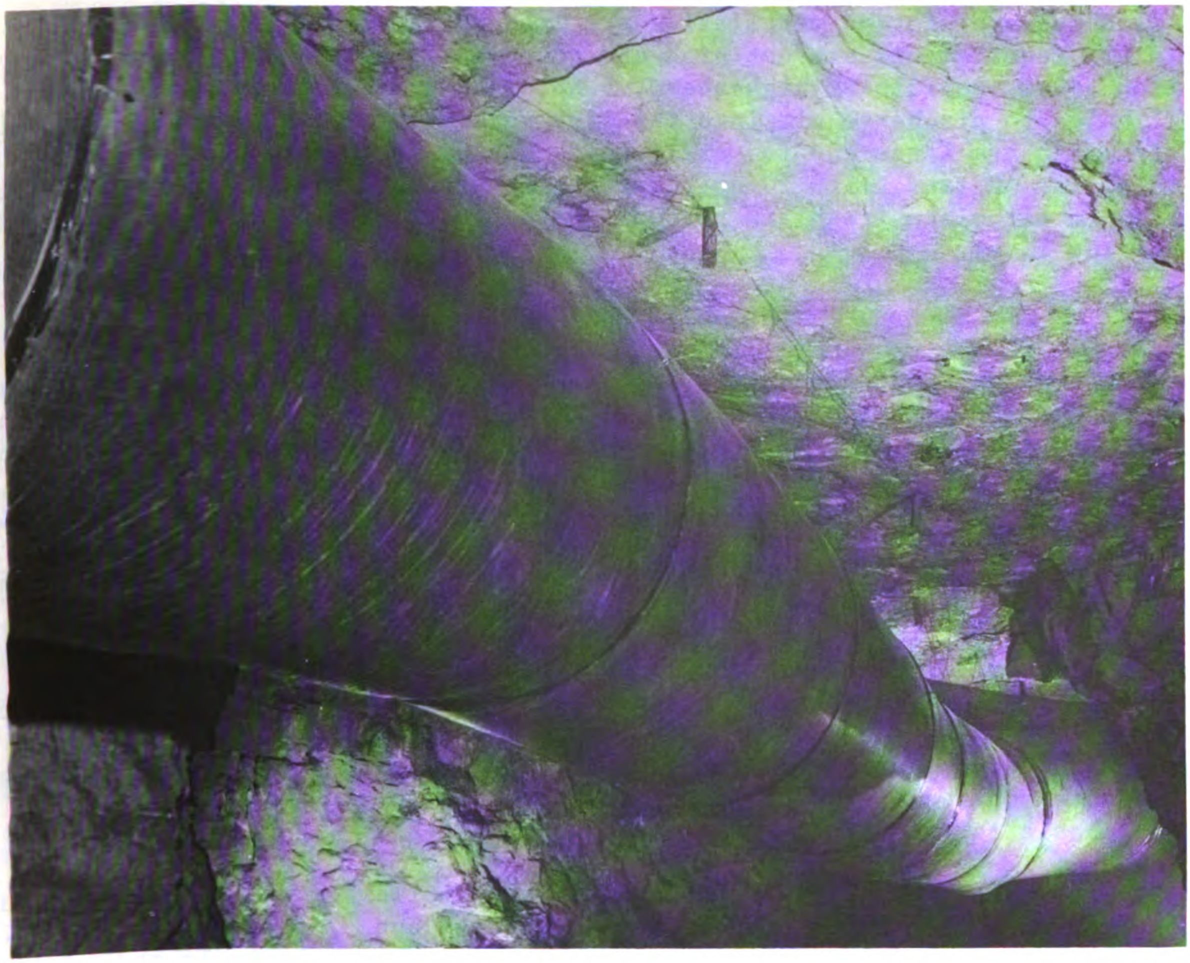

FIGURE 20. - Minerva No. 1 Mine Plastic-Tube Ventilation Line.

Six hundred feet of tubing was installed, 300 feet per shift, using the same number of men and the procedure previously described. The increased production was made possible when the hoop spacing interval was changed from 4 to 8 feet. The cost of installation amounted to $0.30 a foot.

The company considered the tubing to be satisfactory if no failure was observed after a 6-month trial period. Over 2,000 feet of tubing is now in service. It has been installed within 150 feet of the production faces, where severe blasting concussions have not caused tube failure.

Because of the large areal extent of the workings and the many openings to the surface, ventilation at the Crystal-Victory mine is divided into circuits, each of which provides air to certain sections of the mine. Natural ventilating currents supply ample quantities of air for mining operations, except in cases of dead-end workings. While each circuit has its own natural flow characteristics, generally circulation occurs between surface adits and shafts. In the colder months of the year, adits are downcast and shafts upcast; in the warmer months, the direction of flow is reversed.

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Two types of forced ventilation are used to provide air to dead-end areas. Where air requirements are not high and churn-drill holes bottom in the production areas, Buffalo 5E high-speed, 5-hp. fans are set at the collars of the drill holes to discharge air into the mine workings. In instances where air requirements are large and few drill holes bottom in the production area, Buffalo size 40 fans, with 20-hp. electric motors, are placed in the main aircourses to circulate fresh air through 18-inch metal tubing to the dead-end production faces.

MINE DRAINAGE

Under normal conditions very little water seeps into the mine workings at either operation. At the Minerva No. 1 mine, approximately 80 g.p.m. of water is pumped out of the mine by one oil well No. 8P high-pressure duplex piston pump with a 5-inch-diameter piston, an 8-inch stroke, and rated at 180 g.p.m. against a head of 700 feet. The main mine sump is located in the northeast part of the west ore body; the main drainage pump is located at the sump. The water is pumped out of the mine through a 5-inch pipeline placed in a 10-inch churn drill hole. Water enters the sump by gravity from the east ore-body production areas. Because the capacity of the main sump is large and the inflow of mine water relatively small, pumping, which is controlled manually, is done on an intermittent basis. A second oil-well-type 8P duplex pump, which was used to dewater a former haulage level, was installed at the bottom of the main shaft. The water was pumped from the shaft sump to the surface through an 8-inch discharge line hung in the shaft. This pumping unit is now on a standby basis for use if the main drainage pump fails.

Approximately half of the total mine-water inflow occurs in the down-dip northeast production faces of the east ore-body stope. Although the inflow into this area is small (about 40 g.p.m.), water that collects in the production drift faces causes considerable difficulty in drilling and loading operations. Face dewatering is performed by Myers 4- by 5-inch simplex pumps, operating at the faces. This water is pumped through about 200 feet of temporary lines to a shallow sump. The shallow sump is dewatered by a Myers 6- by 8-inch simplex piston pump, which forces water through 750 feet of 2- and 3-inch lines to the mouth of the lower level of the northeast drift, where it enters the east ore-body stope. Water flows by gravity through this drift to the main shaft area, from where it is pumped into the main mine sump in the west ore-body stope.

Production work in the east ore-body stope was transferred from the northeast down-dip faces to the southwest up-dip faces in 1957. Before mining is resumed in the down-dip production faces, a change is planned in the drainage method and equipment to be used in the area. A pilot drainage drift will be driven into the center of the ore body for distances of several hundred feet ahead of the production faces. This drift is expected to drain the ore body well in advance of production operations and will also provide a collecting point of all water inflow in the northeast production area. Two inch suction-pressure diaphragm pumps will be used for face dewatering; these pumps will discharge water through flexible plastic lines to a portable sump tank on a skid mount. A rubber-lined sand pump will be used to pump the water from the portable sump tank, through plastic pipe, and discharge it into the mouth of the lower level of the northeast drift.

Normal water inflow to the Crystal-Victory mine workings does not exceed 100 g.p.m. However, during periods of heavy rains, considerable quantities of surface water may enter the mine through the various adits. Such inflow of surface water is carried downgrade by ditches to three underground collection sumps, one near the Victory-Addison shaft, one near the Crystal No. 3 shaft, and one in an inactive down-dip development heading northeast of the Crystal No. 9 shaft. The Addison shaft sump is dewatered by a 2-inch, five-stage centrifugal pump, which delivers the water against a 180-foot static head to the surface through a 3-inch pump line hung in that shaft. The No. 3 shaft sump is serviced by a 20-hp., eight-stage, 5-inch Pomona pump, set in a 10-inch churn drill hole near the shaft; the pump discharges at the surface and operates against a 120-foot static head. The No. 9 shaft-area pump is a 5-1/2-inch, 10-stage, 30-hp. Pomona pump, which is set in a 10-inch churn drill hole and discharges water at the surface against a 160-foot static head. Sump capacities for both Nos. 3 and 9 areas are large; pumping from these sumps is intermittent and the pumps are manually controlled. The Addison shaft area sump is of limited capacity and the pump serving this sump is automatically controlled by a float switch.

Face dewatering in the Crystal-Victory mine is necessary only in the down-dip areas in the lower workings of the upper Fredonia and Sub-Rosiclare ore horizons; inflow water from up-dip areas flows by gravity to one of the main sumps. Face-dewatering pumps are 2- to 4-inch single-stage, self priming centrifugal units. The pumps, their electric motors, and controls, are mounted on two-wheel rubber-tired carts, and can be moved for rapid movement where needed in the mine. These gathering pumps discharge water into the main sumps or into ditches leading to the main sumps through 2- to 4-inch plastic pipe against static heads that normally do not exceed 50 feet.

HOURS OF WORK, JOB CLASSIFICATION, WAGE RATES

At present, both mines operate on a 5-day week. The workweek comprises 40 hours, two shifts per day, between 7 a.m. Monday and 7 a.m. the following Monday. The day shift begins at 7 a.m. and ends at 3:30 p.m; the evening shift begins at 4 p.m. and ends at 12:30 a.m. A shift premium of 5 cents per hour is paid to men who work the latter shift. When men are required to work the third shift, a shift premium of 8 cents per hour over day-shift rates is paid.

TABLE 2. - Classification and hourly base-wage scale for employees at Crystal-Victory mine, as of December 1957 (union contract UMW District 50)

Classification	Rate per hour
Hoistman, class A (must hoist over 200 tons daily)............	$1.80
Hoistman, class B...	1.75
Shift leader..	2.00
Miner, class A (A roofbolter or a timberman or operates a rockdrill by himself)..........................	1.95
Miner, class B (Operates a rockdrill with a helper or is a helper to a class A miner doing roof-bolting or timbering work)............................	1.85
Raise miner (Draws rate when working above first staging in a raise)..	1.90
Miner helper..	1.75
Truckdriver, underground......................................	1.75
Mucker or apprentice miner....................................	1.68
Underground mechanic..	1.90
Diesel loader operator, underground...........................	1.90

SAFETY AND ACCIDENT-PREVENTION PROGRAM

An active safety and accident-prevention program is in force at all Minerva Oil Co. mines and plants. This program is supervised by a full-time safety director, who is responsible for the coordination of all safety activities, and reports directly to the general manager. The director keeps all accident and related records, supervises first-aid training, presides at safety meetings, distributes safety equipment and literature, and makes frequent inspections of all operations.

Formal safety inspections of mining operations are made at least monthly by a safety committee, which submits a report of all unsafe practices and conditions observed. These reports are reviewed thoroughly and discussed at monthly meetings of the safety director and plant-department supervisors. In reviewing the reports particular attention is given to any failure to correct an unsafe practice or condition observed and noted on previous inspections.

In addition to staff safety meetings, regularly scheduled meetings are held with the mine and surface crews for first-aid training and demonstrations of safe working practices.

Whenever a serious accident occurs, the safety director conducts a meeting of inquiry, which is attended by the general manager, the supervisors concerned, and all witnesses to the accident. The conditions and practices that led to the accident are then investigated, and corrective measures to prevent a repetition of the accident are discussed and adopted.

Hard hats, safety glasses, and hard-toe boots are mandatory for all underground personnel; electric-battery cap lamps are used in all company mines.

All underground working areas are provided with well-stocked first-aid stations where minor injuries are treated.

First-aid stations are provided with stretchers and other equipment required for transporting seriously injured men to the surface for treatment at nearby hospitals. (See fig. 21.)

Interest in these two programs is stimulated by prominently displayed signs and bulletins posted in shops, lunchrooms, and changerooms and by annual safety awards made to individual workmen at a company picnic held each August.

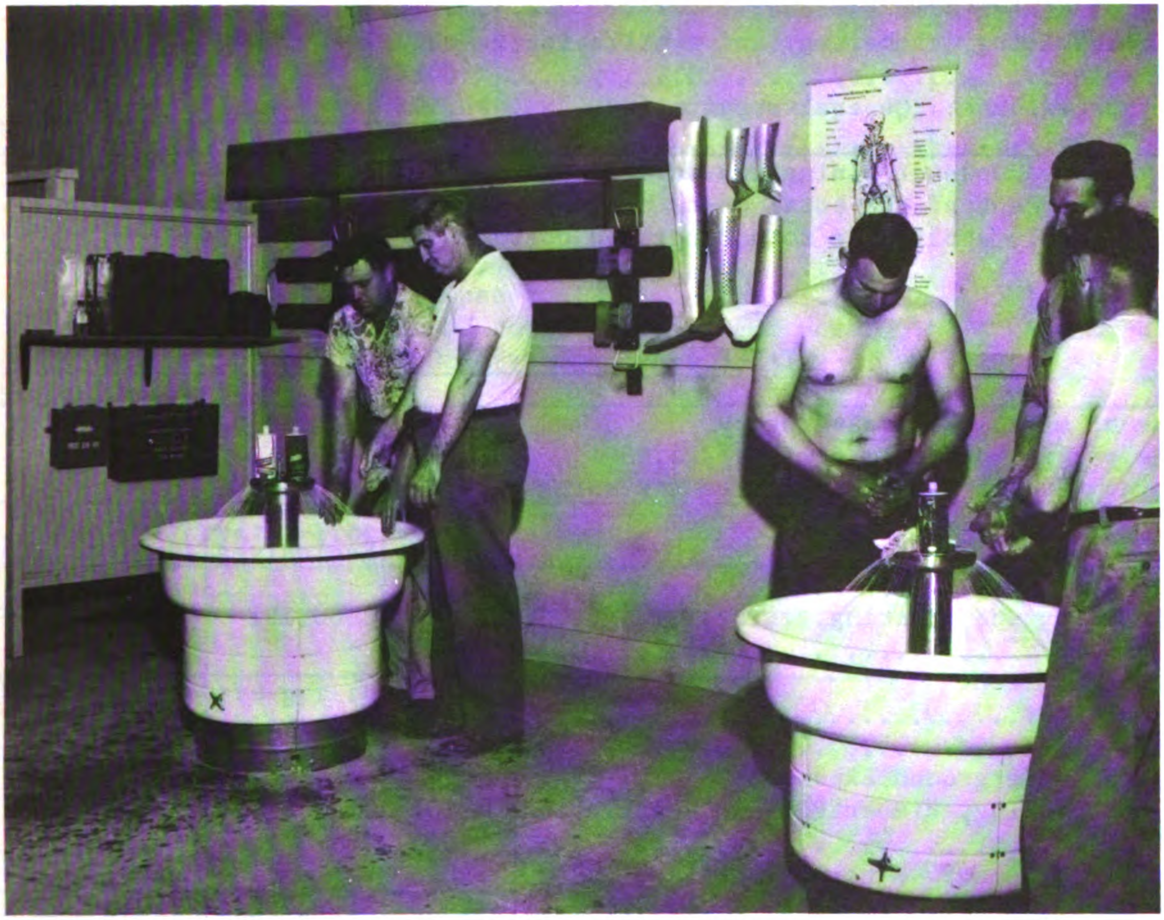

FIGURE 21. - Typical First Aid Equipment Provided for Health and Safety of Employees.

TABLE 3. - Summary of Costs

Name of mine: Minerva No. 1. Period: January, February, March 1958.
Tons of ore hoisted during period: 23,963.
Mining method: Open-stope breast stoping with random pillars.

	Labor[1]	Explosives	Other supplies	Total
Mining:				
Drilling and blasting	$0.359	$0.185	$0.166	$0.710
Loading	.197		.107	.304
Transportation:				
Haulage	.170		.077	.247
Hoisting	.155		.115	.270
General underground expense:				
Roof bolting, timbering, and ventilation	.280		.138	[2] .418
Pumping	.018		.003	.021
Surface expense: General repairs	.195		.020	[3] .215
Total	1.374	.185	.626	2.185

[1] No breakdown of mining and development costs.
[2] 50 percent of the total cost for shaft timbering and rehabilitation.
[3] Directly applicable to underground operation.

TABLE 4. - Summary of Costs

Name of mine: Crystal-Victory. Period: January, February, March 1958.
Tons of ore hauled in period: 24,956.
Mining method: Open-stope breast stoping with random pillars.

	Labor[1]	Explosives	Other supplies	Total
Mining:				
Drilling and blasting	$0.524	$0.191	$0.323	$1.038
Loading	.217		.256	.473
Transportation:				
Haulage	.444		.329	.773
Hoisting				
General underground expenses:				
Roof bolting, timbering, and ventilation	.101		.083	.184
Pumping	.042		.133	.175
Surface expense: General repairs	.095		.030	[2] .125
Total	1.423	.191	1.154	[3] 2.768

[1] No breakdown of mining and development costs.
[2] Directly applicable to underground operation.
[3] An estimated 25 percent of this cost can be charged properly to development.

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TABLE 5. - Summary of costs in units of labor, power, and supplies

Name of mine: Minerva No. 1. Period: January, February, March 1958.
Tons of ore mined and hoisted: 23,963.
Mining method: Open-stope breast stoping with random pillars.

	Mining (stoping) and Development
A. Labor (man-hours per ton):	
Drilling and blasting	0.186
Timbering and roof bolting	.139
Mucking	.102
Haulage and hoisting	.161
Supervision	.024
General[1]	.096
Total labor underground	.708
Average tons per man per shift (all shifts, service and underground)	11.300
Labor, percent of total cost (all shifts, service and underground)	57.02
B. Power and supplies:	
Explosives (pounds per ton)	1.10
Total power (kw.-hr., per ton)	14.20
Other supplies in percent of total supplies and power	66.50
Supplies and power, percent of total cost	42.98

[1] Includes pumping labor.

TABLE 6. - Summary of costs in units of labor, power, and supplies

Name of mine: Crystal-Victory. Period: January, February, March 1958.
Tons of ore mined and hauled through adits: 24,956.
Mining method: Open-stope breast stoping with random pillars.

	Mining (stoping) and Development
A. Labor (man-hours per ton):	
Drilling and blasting	0.246
Timbering and roof bolting	.046
Mucking	.112
Haulage	.233
Supervision	.055
General[1]	.081
Total labor underground	.773
Average tons per man per shift (all shifts, service and underground)	10.349
Labor, percent of total cost (all shifts, service and underground)	49.89
B. Power and supplies:	
Explosives (pounds per ton)	1.25
Total power (kw.-hr., per ton)	12.30
Other supplies in percent of total supplies and power	72.95
Supplies and power, percent of total cost	50.11

[1] Includes pumping labor.

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